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NASA

SPACE SYSTEMS TECHNOLOGY MODEL

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VOLUME III

Opportunity Systems/ Programs and Technologies

May 1980

National Aeronautics and Space Administration
Office of Aeronautics and Space Technology
Code RS
NASA Headquarters
Washington, D.C. 20546

NAS 1.2:

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1. System Program Descriptions
  - Planetary
  - Astrophysics
  - Solar Terrestrial
  - Life Sciences
  - Resource Observation
  - Global Environment
  - Communications
  - Space Transportation
  - Utilization of the Space Environment
  - OAST Instrument Systems
2. Technology Requirements Summary
PART B: Opportunity Systems/Programs from Other Sources
PART C: Opportunity Technologies

NASA

Space Systems Technology Model

VOLUME III: OPPORTUNITY SYSTEMS/PROGRAMS AND TECHNOLOGIES

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INTRODUCTION

This document is the second issue of the Space Systems Technology Model. This issue received NASA-wide inputs and coordination; the first issue was constructed solely for OAST internal usage. This Model will be revised and published on an annual basis. It contains NASA system and program requirements, technology trends, and forecasts for space technology. The Model provides a base of information for guiding technology development for future systems and programs. It also displays the expected availability of technology improvements to enable and/or enhance future missions.

PURPOSE OF THE MODEL

The purpose of the NASA Space Systems Technology Model is to serve as a reference for: planning technology programs and options; identifying technologies required for planned and potential future missions; assessing ongoing technology programs; and providing a technology reference source for mission planning. Ascertaining technology requirements for planned and future missions assures that the focus of technology programs is coupled to the overall goals and missions of NASA.

The system technology needs and requirements presented in the Technology Model do not constitute official agency plans, but may be used in their developments. The Model is a broader menu of candidate and opportunity systems and programs for the future than current funding expectations will allow.

GENERAL DESCRIPTION

The three volumes of the Model treat systems, programs, and technology from the present to reasonable limits of projection.

Volume I contains those systems and programs which the NASA program offices endorse as being within their ten-year planning horizon.

Volume II contains trends and forecasts of space technology.

Volume III provides information about innovative systems, programs, and technology. Part A presents systems and programs which are validated by program offices, but which are either beyond the ten-year planning period or are still deemed speculative. Part B systems and programs derive from sources other than the program offices and, as such, are considered more speculative than Part A missions. Part C presents emerging technologies with little-to-no historical trend, and provides best-possible forecasts of their potential.

The information in the Model has been assembled from a variety of written and oral sources. Validated information contained in the Model has been identified by tracable, formal reference to the responsible NASA Headquarters office. The emphasis is on quantitative descriptions where possible.

The elements presented in the Model include:

1. Mission Systems. An assemblage of hardware and software, ground- or space-based, whose functions are integrated to achieve a program-level objective. Examples are Venus Orbiting Imaging Radar, Space Shuttle, and the National Oceanic Satellite System.

2. Mission Instruments. Scientific equipment for performing experimental or operational measurements which are intended for use in space. Examples are Electromagnetic Containerless Processing System, Solar Backscatter Ultraviolet Spectrometer, and Thematic Mapper.

3. Programs. Funded activities that are approved or are prospective discrete elements of the space budget. Included are: flight programs which use mission and instrument systems to conduct experiments and demonstrate capabilities in space. Examples are the Space Science Platform and the Large Space Structures System Technology and Development Plan. Investigatory programs which are nonflight specific aggregations of activities, often analytic in nature but which may contain flight elements. Examples are 30/20 GHz Wideband Communications satellite program and the National Materials Laboratory. Functional service programs which provide users with space-derived information, capabilities, or methods. An example is the Application Data Service Development program.

In summary, the items presented are the implements which NASA has or envisions to achieve the perceived goals of the civil space program. These goals are expressed in the NASA Five-Year Planning Document, published annually, and this Model serves as a supplement to the current "Five-Year Plan."

The content of the three volumes and their parts has been selected to maintain a clear distinction between different levels of planning information (see Fig. 1). The information in Volume I is for definitive programs, i.e., systems and programs which are approved, planned, or candidates for initiation within the next ten years (see Fig. 2 for definition of these categories). The information contained in Volume III, for systems and programs expected to start after ten years, can be strongly influenced by new technology. Figure 3 shows the relationship

WITHIN TEN-YEAR HORIZON

VOLUME I

System/Program Descriptions and Technology Needs

- Part A: System/Program Summary and Schedule
- Part B: Detailed System/Program Descriptions and Required Technology
- Part C: Technology Requirements Summary

VOLUME II

Space Technology Trends and Forecasts

- Arranged by Disciplines
  - Power and Electric Propulsion
  - Chemical Propulsion
  - Materials and Structures
  - Information Systems
  - Navigation, Guidance and Control
  - Automated Operations

DISTANT HORIZON

VOLUME III

Opportunity Systems/Programs and Technologies

- Part A: Program Office Opportunity Systems and Programs
- Part B: Opportunity Systems and Programs from Other Sources
- Part C: Opportunity Technologies

TECHNOLOGY PLANNING

VOLUME IV

Analysis of Technology Needs and Future Considerations

- Will relate system/program needs to technology development
- Will discuss technology innovations and their potential effects on system and program planning

Figure 1. NASA Space Systems Technology Model

VOLUME I

APPROVED - A

MISSIONS WHICH HAVE BEEN FUNDED AND AUTHORIZED FOR IMPLEMENTATION.

PLANNED - P

MISSIONS DESIGNATED BY THE PROGRAM OFFICES AS POSSIBLE NEW STARTS WITHIN THE NEXT FIVE YEARS.

CANDIDATE - C

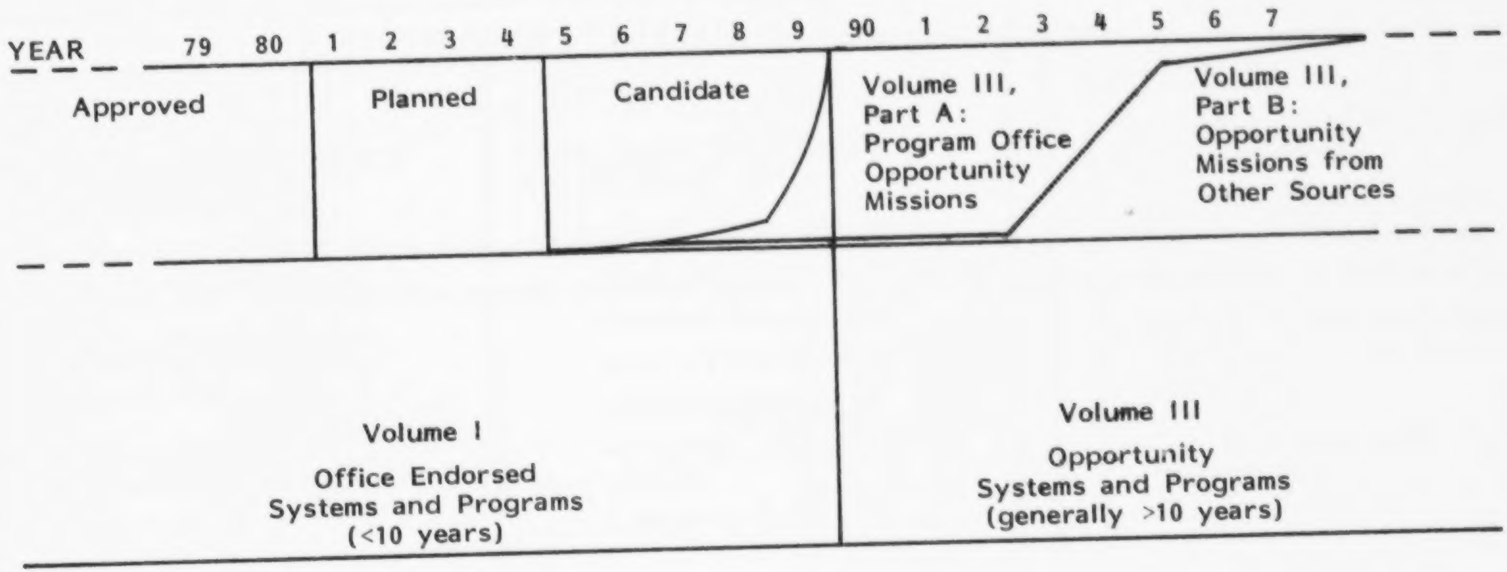
MISSIONS CONSIDERED FOR POSSIBLE INITIATION WITHIN TEN YEARS, BUT CURRENTLY NOT PLANNED AS A NEW START WITHIN THE NEXT FIVE YEARS.

VOLUME III

OPPORTUNITY - O

POTENTIAL MISSIONS FOR START BEYOND TEN YEARS AND/OR THOSE MISSIONS OF A SPECULATIVE NATURE. SUCH MISSIONS PROVIDE OPPORTUNITIES FOR TECHNOLOGY DEVELOPMENT TO SHAPE SYSTEM DESIGNS.

Figure 2. Categories of Systems and Programs


YEAR
79
80
1
2
3
4
5
6
7
8
9
90
1
2
3
4
5
6
7
Approved
Planned
Candidate
Volume III, Part A: Program Office Opportunity Missions
Volume III, Part B: Opportunity Missions from Other Sources
Volume I
Office Endorsed Systems and Programs (<10 years)
Volume III
Opportunity Systems and Programs (generally >10 years)

NOTE: Systems/programs are included in Model if flight or start is 1979 or later.

Figure 3. Model Presentation of NASA Systems and Programs

between the categories, time, and the volumes of this Model. The technology trends and forecast information has been similarly separated into two volumes. Volume II presents data for ongoing and forecastable technology developments. Volume III, Part C presents data on opportunity technologies which have no current credible system or program applications or which cannot be forecasted now.

VOLUME I

Volume I, System/Program Descriptions and Technology Needs, contains details on systems and programs endorsed by the responsible program offices for a start in the next ten years. Identification of the systems and programs and their relative time phasing was obtained from the program offices at NASA Headquarters by means of several iterated reviews over the last six months. Technical characteristics of the systems and programs were compiled to the extent available and subjected to review and validation by the responsible program offices.

The systems and programs are grouped in categories corresponding to basic NASA program areas: Planetary, Astrophysics, Solar Terrestrial, Life Sciences, Resource Observation, Global Environment, Communications, Space Transportation, Utilization of the Space Environment, and Technology Development (OAST instrument systems). They are sequenced by funding and/or development status (Fig. 2). Funded, ongoing systems and programs are designated Approved. Those identifed as possible new starts within the next five years are designated as Planned. Systems and programs identified as new starts within the present five-year plan period but considered for possible initiation within ten years are designated Candidate. Those potentially starting after ten years and/or those of a speculative nature are designated Opportunity; they are presented in Volume III.

Volume I is arranged in three parts:

Part A: System/Program Summary and Schedule

- This is a chronological list of systems and programs by program area (Planetary, Astrophysics, etc.). The list includes system/program name, status, source, start data for major effort, launch data if applicable, and primary contact for information.
- At the end of Part A, the start dates are displayed graphically by program area.

Part B: Detailed System/Program Descriptions and Required Technology

A section for each mission system or program presents technical details.

- The first page presents general information: an illustration; basic features; and narrative on objective, description, technology needs, references, and contacts.
- Following pages present technical characteristics to the extent that they are now known or relevant. A technical characteristic is generally presented as a nominal value, the degree of confidence in the value, and the state of technology readiness. Comments are provided to explain particular conditions.
- Instrument systems are presented in a format which contains name, status, carrier, physical and general properties, principal purpose and features, principal physical property measured, associated ranges and resolutions, comments, sources, and contacts. For the science programs (Planetary, Astrophysics, Solar Terrestrial, and Life Sciences) the instrument systems are not presented separately, but are grouped on a sheet with the related mission system.

Part C: Technology Requirements Summary

- Values of particular technical characteristics are tabulated for all mission systems. The data are further presented versus time. Analysis of the plotted data should reveal trends in technology demanded by the aggregate of NASA mission systems and programs envisioned for the next ten years. In Volume III, Part A, the characteristics of mission systems and programs beyond ten years are added to these plots.

VOLUME II

Volume II, Space Technology Trends and Forecasts, presents data characterizing space technology developments. The present and projected status of space technology is arranged by discipline: power and electric propulsion; chemical propulsion; materials and structures, information systems; navigation, guidance and control; and automated operations. Past technology trends, state of the art, and a ten-year or more forecast of capabilities are included.

These forecasts were obtained from NASA technology development managers at Headquarters and the Centers. The technology development managers were asked to identify figures of merit for technology discipline and forecast their growth. The resulting set of forecasts in Volume II can be related in many cases to Volumes I and III system and program characteristics.

VOLUME III

Volume III, Opportunity Systems/Programs and Technologies, is divided into three parts:

- Part A: Program Office Opportunity Systems and Programs, presents technical details on systems and programs which the offices endorse but which are speculative or beyond ten years. The format is identical to Volume I, Parts B and C. These missions are called "opportunity" because there is ample time for vigorous technology development to greatly impact their form and feasibility.
- Part B: Opportunity Systems and Programs from Other Sources, presents a selection of systems and programs which cannot now be advocated by the NASA program offices for various reasons; they are too distant, too speculative in feasibility, pertinence, or utility; or too controversial.
- Part C: Opportunity Technologies, presents information on emerging technologies. Opportunity technology often provides revolutionary advances which may enable otherwise unachievable mission systems. The format is a one-page description of contacts, character, relation to mission and instrument systems and other technologies, status descriptors, and coarse forecasts.

VOLUME IV

(to be supplied at a later date)

Volume IV, Analysis of Technology Needs and Future Considerations, was to relate system and program needs to technology development and discuss technology innovations and their potential effects on mission and program planning. As of the date of this issue, Volume IV has not been produced. NASA Headquarters, supported by the Centers, is preparing technology development plans which would form the essence of this volume. Drafts of Volumes I, II, and III of the Model served as the primary basis for preparing these plans. Further evolution will lead to a presentation of technology plans in a formal Volume IV.

MODEL USE AND MAINTENANCE

The NASA Space Systems Technology Model is an outcome of the space technology program planning and implementation process. The Model is intended to be a companion to the NASA Five-Year Planning Document and will be updated annually. It is believed that the Model will improve steadily through subsequent iterations.

Requests for additional copies of the Model should be addressed to Stan Sadin, Code RS-5, NASA Headquarters, Washington, DC 20546. Comments and suggestions for additional information to be included in future updates should be sent to the same address.

ACKNOWLEDGMENTS

This Model is the product of support from many organizations and individuals. An acknowledgment of the contributors appears at the end of this volume.

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PART A: OPPORTUNITY SYSTEMS/PROGRAMS FROM PROGRAM OFFICES

This part presents the systems/programs which are envisioned by the program offices for start beyond ten years (1990+), or which the program offices consider speculative but potentially a start before 1990.

The system/program requirements information is presented in the same format as in Volume I, Part B. Included on the forms are the names of contacts, responsible offices, and other pertinent data on the source of the information presented. The second portion of Part A is a summary of the technology data. The data are presented in tabular form by discipline, and where possible are plotted as a function of start date (Technology Readiness Date). For comparison purposes the plots include the near-term system/program data presented in Volume I, Part C.

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1 SYSTEM/PROGRAM DESCRIPTIONS AND REQUIRED TECHNOLOGIES

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PLANETARY

The Planetary program consists of reconnaissance, exploration, and intensive study missions to various solar system bodies. Reconnaissance missions to seek and identify major characteristics are generally accomplished by flyby spacecraft; exploration missions to discover and understand processes, history, and evolution on a global scale are best accomplished by using orbiting spacecraft in combination with entry bodies and landers; and intensive study missions focused on specific science issues are accomplished using mobile vehicles, sample return or on-location analysis laboratories, and low-altitude polar orbiters.

Investigation of solar system bodies follows an evolution from reconnaissance, through exploration, to intensive study. For Mars and the moon, the exploration phase has been completed and the intensive study realm of investigation is being entered. The reconnaissance phase is nearly completed for Venus and Mercury, and has begun for Jupiter, Saturn, and their moons. Reconnaissance missions to primitive bodies (comets and asteroids), the outer planets, and more satellites of the giant planets are in the planning stages.

PLANETARY MISSIONS

No.

P-7 Asteroid Multiple Rendezvous consists of one spacecraft designed to explore 4-8 asteroids in the main belt.

P-8 Lunar Polar Orbiter provides the opportunity to capitalize on our present data and understanding of the earth's moon.

P-9 Mercury Orbiter and Lander provides an opportunity to study the dynamics of magnetospheres, comparative analysis of crustal chemistry and evolution, and a test bed for various solar physics experiments.

P-10 Comet Sample Return offers a unique opportunity to acquire material that has changed little since the origin of the solar system.

P-11 Near Earth Asteroid Sample Return is to provide a surface sample from at least one asteroid.

P-12 Venus Lander provides for in situ investigation of the local surface and interior of Venus.

P-13 Automated Mobile Lunar Surface is to make a detailed survey of the lunar surface.

P-14 Automated Planetary Station provides the opportunity for continuous observation of dynamic phenomena.

P-15 Lunar Backside Lander and Sample Return is to return a surface sample from the backside of the moon.

P-16 Ganymede Lander is to deploy a semi-hard lander vehicle on the surface of this Jovian satellite for in situ observation.

PLANETARY

MISSION: ASTEROID MULTIPLE RENDEZVOUS P-7

Status: Opportunity

Lifetime: 6 to 10 years launch to end-of-mission

Launch and Transfer Vehicles: Shuttle/IUS(Twin) plus SEPS

Operational Location: Rendezvous with several main belt asteroids

Total Mass at Operational Location: 2000 kg at last asteroid

Average Operational Power: 30 kw (for SEPS)

OBJECTIVE: The Asteroid Multiple Rendezvous mission allows one spacecraft to explore 4-8 asteroids in the main belt. The science objective is to study a variety of asteroids (compositional type, size, etc.) using high resolution imagery and remote sensing instruments for geochemical and geophysical measurements. In-situ experiments can be accommodated by deploying penetrators or hard landers as it orbits an asteroid.

DESCRIPTION: The AMR mission would be launched on a Shuttle/IUS and would use a Solar Electric Propulsion stage to effect the heliocentric transfer to the asteroid belt and between targets. The SEP stage would be used to achieve a captured orbit about a selected target. Observations would be made during a 60-day stay. The low thrust propulsion system would then be used to escape from that asteroid and to propel the spacecraft on to the next target. This mission is preferred for asteroid exploration because it conducts detailed investigations at each target and it studies multiple asteroids from the diverse population in the main belt. A multiple asteroid flyby mission returns much less data from each target.

CRITICAL TECHNOLOGY NEEDS: A concentrated solar array is needed for the SEP stage. Penetrators or hard landers would require development effort unless they are used for an earlier planetary mission.

INSTRUMENT OR EXPERIMENT COMPLEMENT: For the orbiting spacecraft--high resolution imagery reflection spectroscopy, gamma ray spectroscopy, X-ray fluorescence, radar altimeter, microwave radiometer and some particle and field detectors. For the lander--alpha particle scattering, imagery, seismometry.

REFERENCES: "Asteroid Multiple Rendezvous Mission Concept: A Preliminary Description" JPL Technical Document 710-26, February 1979.
"Asteroid Mission Study" SIA Report No. 1-120-839-M11, May 1979.

CONTACTS: R. J. Boain, JPL, (213)354-2947
W. C. Wells, SAI, (312)885-6800

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: ASTEROID MULTIPLE RENDEZVOUS P-7

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Physical Character			
Overall dimension(m)	35x5x5	3, SOA	
Total Mass (kg)	2000	3	At last target
Mass breakdown (kg)			
Mission module	550	3	Includes about 100 kg for science instruments.
SEPS	1450	3	
Deployed/articulated items, size (m)			
Solar arrays	35x8	3, SOA	1 degree of freedom; with concentrators
Science boom	10-20	3, SOA	
Science Scan Platform	ND	3	2 degrees of freedom
High Gain Antenna	1.5 dia	3, SOA	2 degrees of freedom
Life			
Flight duration (years)	6-10	3, SOA	4 asteroids in 6 years; up to 8 in 10 years.
Number of spacecraft	1	3	Plus penetrators/hard landers, if used.
Orbit			
Periapse/apoapse altitudes (km)	ND	3	Spacecraft establishes high orbit (> 10 asteroid radii) to observe shape, study gravity field. Lower orbit is desired and is selected after initial data is reduced.
Inclination (deg)	ND	3	

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: ASTEROID MULTIPLE RENDEZVOUS P-7

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Data			
Data volume (bits/day)	10^9	3, SOA	
Storage			
Capacity (bits)	2x10^9	3, SOA	Galileo tape recorders
I/O rates (kbps)	120	3, SOA	Galileo tape recorders
Spacecraft processors/ computers			
I/O rates (kbps)	ND	3	Distributed microprocessors; low data rates except for imagery.
Memory size (bits)	ND	3	
Ground Processors/ computers			
Memory size (bits)	ND	3	Use existing systems with some software improvements to reduce gravity field data quickly.
Communications			
Minimum/maximum downlink rates (kbps)	0.2 - 120	3, SOA	Direct link from spacecraft to Earth through DSN. S- and X-band for digital data. Spacecraft is relay for penetrator or hard lander, if used.
Uplink rate (kbps)	ND	3	
Guidance & Attitude Control			
View direction	Varies	3, SOA	3-axis stabilized attitude control with articulated solar arrays, high gain antenna and science scan platform. Pointing for thrust vector control during cruise and orbit maneuvers; Nadir pointing possible while in orbit about asteroid. Requirements are similar to comet rendezvous so technology is SOA.
Position accuracy (km)	ND	3	
Pointing accuracy (mrad)	ND	3	
Stability (mrad)	ND	3	

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: ASTEROID MUPTIPLE RENDEZVOUS P-7

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Power			
Average power consumed (We)	400	3, SOA	Power provided by SEPS Photo voltaic solar cell with concentration; peak power available when thrusters are off.
Peak power consumed (We)	700	3	
Power breakdown (We)	ND	3	
Energy Storage			
Storage capacity (J)	ND	3	
Discharge rate (We)	ND	3	Batteries may be needed in mission module to support spacecraft during solar occulations which could occur when it is orbiting an asteroid at a low altitude.
Discharge/recharge times (min)	ND	3	
Thermal Control			
Component temperature (K)	ND	3	No unusual requirements have been identified; existing technologies can be used.
Component load (Wt)	ND	3	

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: ASTEROID MULTIPLE RENDEZVOUS P-7

Mission Parameters (units)	Value	Confidence Level, Technology State	Comments
Chemical propulsion			
Total ΔV required (m/sec)	NA		
Number of stages			
First Stage			
Thrust level(N)			
Isp (sec)			
Propellant mass (kg)			
Inert mass (kg)			
Second Stage			
Thrust level(N)			
Isp (sec)			
Propellant mass (kg)			
Inert mass (kg)			
Low-Thrust Propulsion			
Input power (kWe)	31.6	3, SOA	2:1 concentration needed;
Stage mass (kg)	1450	3, SOA	
Propellant (kg)	2500	3, EV	Large propellant loading may require some increase in thruster lifetime beyond nominal 30,000 Ah.
Atmospheric Deceleration			
Entry speed (km/sec)	NA		
Ballistic coefficient (kg/m^2)			
Terminal velocity (m/sec)			

PLANETARY
SENSOR/EXPERIMENT PARAMETERS

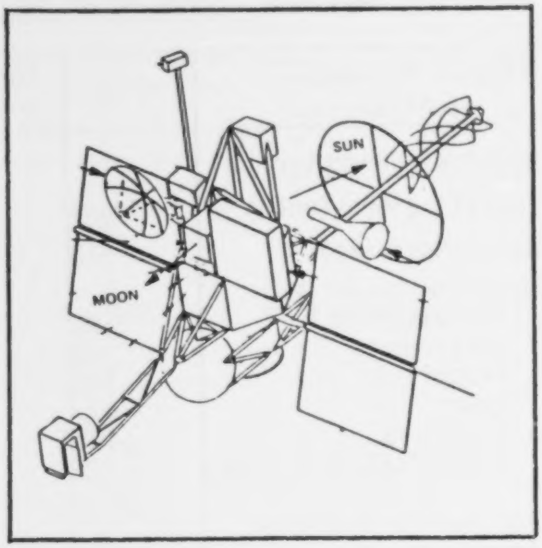
MISSION: ASTEROID MULTIPLE RENDEZVOUS P-7

Sensor or Experiment Name	Physical Property Measured/Property Range & Accuracy Resolution	Associated Ranges and/or Resolutions	Purpose, Component Properties, Other Comments
Imaging	Reflected radiance from asteroid	Spectral range of 0.3 to 1.1 μm with resolution of 0.1 μm (3, SOA). Angular resolution of about 10 μrad and FOV of 0.5 deg. (3, SOA)	A CCD array sensor with a 800 x 800 format(3,SOA) Provides global and high resolution maps of surface features.
Gamma Ray Spectrometer	Gamma ray emission from material and induced radionuclides. Rate is ≈ 10/cm^2/sec; accuracy is limited by background.	Energy range of 0-8000 keV and resolution of 2 keV (3,EV); Spatial resolution is determined by orbit altitude; long observing time needed.	100 cm^3 detector volume (3,EV) of intrinsic germanium. Instrument mass is 12 kg (3,SOA) and is mounted on boom to reduce background. Energy resolution by pulse height analysis. Surface elemental composition deduced from the observed spectra.
X-ray Fluorescence Spectrometer	X-ray fluorescence excited by solar x-rays interacting with asteroid surface.	Energy range is 0-8 keV and resolution is 0.25 keV (3, SOA). Angular resolution is 20 deg. (3, SOA)	Proportional counters(3) with window areas of 50 cm^2 and thickness of 25 μm (3,SOA). Metal filters and pulse height analysis used for energy resolution. Mass is 10kg deg. (3,SOA).
Reflectance Spectrometer	Reflected radiance from asteroid with 0.1% resolution.	Spectral range of 0.35 - 2.5μm and resolution of 0.1μm (3,EV); Angular resolution of 0.5 deg. (3,SOA)	Si diodes and PbS are detectors; PbS cooled to 223K (3,SOA); Mineralogy deduced from position strength of spectral absorption features.

PLANETARY

MISSION: LUNAR POLAR ORBITER P-8

Status:	Opportunity
Lifetime:	1 year in lunar orbit
Launch and Transfer Vehicles:	Shuttle/SUSS-D
Operational Location:	Lunar orbit (circular, 100 km, polar)
Total Mass at Operational Location:	300 kg (without propellant)
Average Operational Power:	160 w



OBJECTIVE: The Lunar Polar Orbiter (LPO) mission provides the opportunity to capitalize on our present data and understanding of the Earth's Moon for substantial progress toward a fundamental goal--to understand the initial conditions in the solar nebula, the processes of formation and evolution for planetary bodies and the present active processes in the solar system. LPO is also useful for evaluating the availability of lunar resources.

DESCRIPTION: The LPO mission was considered by the Planetary Division of NASA's Office of Space Science (Code SL-4) as a candidate new start in FY 78 and FY 79, but is no longer under active consideration for a new start. LPO is a dual spacecraft mission. There is an orbiter which carries all the science instruments and there is a small subsatellite. Following a 115 hour flight to the Moon and two weeks in an initial elliptical orbit, the orbiter deploys the subsatellite, circularizes its own orbit and then makes periodic adjustments to maintain this orbit. The orbiter is a three-axis-stabilized spacecraft; one axis defined by the remote-sensing science instruments points to the nadir while the solar panels track the sun. Some instruments acquire data continuously, others only with favorable solar illumination. Tracking of the subsatellite and of the orbiter via the subsatellite are used for gravity field determination.

CRITICAL TECHNOLOGY NEEDS: LPO uses current state-of-the-art technology. Low cost is an important factor.

INSTRUMENT OR EXPERIMENT COMPLEMENT:

- Gamma ray spectrometer
- Array fluorescense
- Reflectance spectrometer
- Radar altimeter and tracking
- Microwave radiometer
- Spectro-stereo imager
- Magnetometer
- Electron reflection

REFERENCES: "Mission Summary for Lunar Polar Orbiter", J. W. Minear, N. Hubbard (JSC), T.V. Johnson., V. C. Clarke, Jr. (JPL), JPL Document No. 660-41, September 1976.

"Lunar and Planetary Mission Handbook-Vol. IV: Mission Descriptions", JPL Document No. 710-14, May 1979.

CONTACTS:

J. D. Burke, JPL (213)354-6363
T. V. Johnson, JPL, (213)354-7427

MISSION TECHNOLOGY REQUIREMENTS

MISSION: LUNAR POLAR ORBITER P-8

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Physical Character			
Overall dimension(m)	4x6x4	2, SOA	Launch configuration is 2x2x4.
Total Mass (kg)	510	2, SOA	
Mass breakdown (kg)			
Subsatellite	28	2, SOA	
Instruments	65	2, EV	
Propulsion	189	2, SOA	
Power	22	2, SOA	
Structure	108	2, SOA	
Communications, data	29	2, EV	
Deployed/articulated items, size (m)			
Subsatellite	1.0	2, SOA	
Deployed science	1.0	2, SOA	Magnetometer, γ-ray.
Solar array(s)	1.3	2, SOA	Both items are single-degree-of-freedom.
Medium-gain antenna	0.3	2, SOA	
Life			
Flight duration (years)	1.0	2, SOA	1/2 year for full coverage of moon at all solar illuminations; two such cycles planned.
Number of spacecraft	1	2	
Orbit			
Periapse/apoapse altitudes (km)	100/100	2	Subsatellite orbit is 100/3424 with periapse location chosen to have stable orbit requiring no adjustments.
Inclination (deg)	95	2	

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: LUNAR POLAR ORBITER P-8

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Data			
Data volume (bits/day)	10^8-10^9	2, SOA	
Storage			
Capacity (bits)	4×10^8	2, SOA	NASA Std. tape recorder
I/O rates (kbps)	180	2, SOA	
Spacecraft processors/ computers			
I/O rates (kbps)	ND	2, EV	Distributed microprocessors; I/O rates low except for imagery data
Memory size (bits)	ND		
Ground Processors/ computers			
Memory size (bits)	ND	2, SOA	Mission operations center processes engineering/science data and generates uplink commands. Computer resources are not new.
Communications			
Minimum/maximum downlink rates (kbps)	4-180	2, SOA	To DSN direct from orbiter and from subsatellite and from orbiter via subsatellite (bent pipe). S-band except orbiter to subsatellite which is UHF; all links are digital. Imagery/ recorded data via medium gain antenna.
Uplink rate (kbps)	0.250	2, SOA	
Guidance & Attitude Control			
View direction	Nadir	2, SOA	Sensors are sun angle sensor, horizon scanners and gyros; actuators are reaction wheels and thrusters. Requirements given for high resolution imagery. Orbiter is spin stabilized until it reaches its final circular orbit.
Position accuracy (km)	ND	2, SOA	
Pointing accuracy (mrad)	1.0	2, SOA	
Stability (mrad)	.1	2, SOA	

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: LUNAR POLAR ORBITER P-8

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Power			
Average power consumed (We)	0.16	2, SOA	Photovoltaic
Peak power consumed (We)	0.24	2	Duration estimated to be 60 min.
Power breakdown (We)			
Instruments	68	2	
Battery charging	100	2	
Attitude control	15	2	
Data, communications	45	2	
Propulsion	17	2	
Energy Storage			
Storage capacity (J)	10^6	2, SOA	NASA Standard NiCd batteries 9 Ah.
Discharge rate (We)	120	2	
Discharge/recharge times (min)	30/60	2	
Thermal Control			
Component temperature (K)			
S/C electronics	280	2	Assumed, typical
Propulsion/Science	ND	2	
Component load (Wt)			
S/C electronics	ND	2	Controlled by blankets, louvers
Propulsion/Science	17	2	supplied by heaters.

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: LUNAR POLAR ORBITER P-8

Mission Parameters (units)	Value	Confidence Level, Technology State	Comments
Chemical propulsion			
Total ΔV required (m/sec)	948	2	
Number of stages	2	2	
First Stage			
Thrust level(N)	11,000	2	
Isp (sec)	ND	2	
Propellant mass (kg)	70	2, SOA	Solid propellant for lunar orbit insertion (to 100 x 3424 km)
Inert mass (kg)	ND	2	
Second Stage			
Thrust level(N)	88/1	2, SOA	Liquid (hydrazine) for mid-course corrections orbit circularization and orbit adjustments
Isp (sec)	240	2	
Propellant mass (kg)	87	2	
Inert mass (kg)	ND	2	
Low-Thrust Propulsion			
Input power (kWe)	NA		
Stage mass (kg)			
Propellant (kg)			
Atmospheric Deceleration			
Entry speed (km/sec)	NA		
Ballistic coefficient (kg/m^2)			
Terminal velocity (m/sec)			

PLANETARY

SENSOR/EXPERIMENT PARAMETERS

MISSION: LUNAR POLAR ORBITER P-8

Sensor or Experiment Name	Physical Property Measured/Property Range & Accuracy Resolution	Associated Ranges and/or Resolutions	Purpose, Component Properties, Other Comments
Gamma Ray Spectrometer	Gamma ray emission from material and induced radionuclides. Rate is $\approx 10/cm^2/sec$; accuracy is limited by background.	Energy range of 0-8000 keV and resolution of 2 keV (2,EV); Spatial resolution of 50 km (2,SOA) is determined by orbit altitude; long observing time needed.	100 cm^3 detector volume (2,EV) of intrinsic germanium. Mounted on boom to reduce background. Energy resolution by pulse height analysis. Surface elemental composition deduced from observed spectra.
X-ray Fluorescence Spectrometer	X-ray fluorescence excited by solar x-rays interacting with lunar surface.	✓Energy range is 0-8 keV and resolution is 0.25 keV (2,SOA). Spatial resolution is 10 km. (2,SOA).	Proportional counters(3) with window areas of 50 cm^2 and thickness of 25 μm(2,SOA). Metal filter and pulse height analysis used for energy resolution. Surface elemental composition deduced from observed spectra.
Reflectance Spectrometer	Reflected lunar radiance with 0.1% resolution.	Spectral range of 0.35 - 2.5μm and resolution of 0.01μm (2,EV); Spatial resolution of 0.5 km (2,SOA).	Si diodes and PbS are detectors; PbS cooled to 223K(2,SOA). Mineralogy deduced from position, strength of spectral absorption features.
Spectro-stereo Imaging	Reflected lunar radiance	Spectral range of 0.3 to 1.1μm (2,SOA). Spatial resolution of 0.15 km (2,SOA).	Six 1000 element linear arrays (2,EV) provide different combinations of spatial resolution/spectral range. Produces ground track images as high resolution multispectral and stereo maps of selected access.
Microwave Radiometer	Emitted lunar thermal energy at $\approx$300K with 0.1K resolution.	Emission measured at 3.6, 10.7 and 20.0 cm; spatial resolution of 50 km.	Internal calibration source. Each band has an antenna with identical beams. Uses horizon sensors to measure surface temperature. Microwave emission gives internal heat flow.

PLANETARY

MISSION: MERCURY ORBITER AND LANDER P-9

Status: Opportunity

Lifetime: 1-4 years including at least 6 mo. in Mercury orbit.

Launch and Transfer Vehicles: SEPS optional

Operational Location: Mercury orbit and surface

Total Mass at Operational Location: 300-800 kg in orbit
100 kg on surface

Average Operational Power: 300-600 w.

OBJECTIVE: Following Mariner 10's discoveries, an orbiter mission to Mercury is the next logical stop in its exploration. Mercury occupies a unique place in solar system physics by virtue of its closeness to the Sun, its high density, and its unusual magnetic field. A mercury obriter can provide a great advance in understanding the dynamics of magnetospheres by probing a magnetosphere having different parameters than Earth's. Mercury provides an excellent opportunity for a comparative analysis of its chemical composition and crustal evolution with that of the Moon. A Mercury orbiter also affords an excellent natural test bed for solar physics experiment and for relativistic theories of gravitation.

DESCRIPTION: An orbiter mission to Mercury can be delivered via a ballistic trajectory with multiple Venus swingbys or a low thrust trajectory using Solar electric propulsion (SEPS). (Solar Sail is an alternate low-thrust propulsion system for this mission.) Two types of orbiters have been proposed. One is a nadir pointing spacecraft in a circular polar orbit. It carries remote sensing instruments (imaging, geochemical and geophysical). The other is a smaller, spin-stabilized spacecraft in an elliptical orbit; instrumentation is primarily for particles and fields. Both hard landers and penetrators have been proposed to perform the in-situ surface measurements. A single mission might consist of one orbiter, two orbiters or an orbiter and one type of lander.

CRITICAL TECHNOLOGY NEEDS: High temperature environment requires new technology for orbiter spacecraft, landers and low-thrust propulsion systems. Solar and relativity experiments require improvements in systems used to determine the spacecraft orbit. A Solar Thermoelectric generator (SGT) is the preferred orbiter power source.

INSTRUMENT OR EXPERIMENT COMPLEMENT: Many of the instruments for a Mercury orbiter mission could be similar to the Lunar Polar Orbiter. Surface instruments might include imagery, alpha particle scattering, X-ray spectroscopy and seismometry. Solar/relativity experiments are a neutron-detector and precision orbit determination.

REFERENCES: J. French, et.,al.
"New Concepts for Mercury Orbiter Missions", JPL Document No. 760-190, 1977.

CONTACTS: C. Uphoff, JPL, (213)354-3054
J. French, JPL, (213)354-5602

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: MERCURY ORBITER AND LANDER P-9

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Physical Character			
Overall dimension(m)	ND	3, SOA	
Total Mass (kg)	300-800	3	
Mass breakdown (kg)	ND	3	
Deployed/articulated items, size (m)			
Science Boom(s)	3-10	3	For magnetometer, γ-ray.
High gain antenna	1.5-3	3	Articulated on 2 axes to view Earth.
Solar Thermal generator	ND	3	
Life			
Flight duration (years)	1.5-3.0	3	Range due to trajectory options; includes one year on orbit.
Number of spacecraft	2	3	Orbiter and Lander probably launched together.
Orbit			
Periapse/apoapse altitudes (km)	500/500	3	For nadir pointing spacecraft. Apoapse of about 5000 km for spin-stabilized spacecraft. Lander/orbiter communications with each other and Earth. Different orbit may be needed when spacecraft is relaying lander data.
Inclination (deg)	90	3	

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: MERCURY ORBITER AND LANDER P-9

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Data			
Data volume (bits/day)	10^8-10^{10}	3, SOA	Particles and fields vs. multispectral remote sensing.
Storage			
Capacity (bits)	ND	3, SOA	Depends on imaging system; could be tape recorder or bubble memories.
I/O rates (kbps)			
Spacecraft processors/ computers			
I/O rates (kbps)	ND	3	Distributed microprocessors; data rates low except for imaging.
Memory size (bits)	ND	3	
Ground Processors/ computers			
Memory size (bits)	ND	3	Use existing capabilities.
Communications			
Minimum/maximum downlink rates (kbps)	1-120	3, SOA	Orbiter data is digital; Transmitted on S-and X-band direct to DSN; lander data transmitted to relay spacecraft.
Uplink rate (kbps)	ND	3	
Tracking accuracy	ND	3, EV	Improvements in tracking systems on spacecraft and on ground may be needed to determine orbits with accuracy desired for solar physics/relativity experiments.
Guidance & Attitude Control			
View direction	ND	3, SOA	
Position accuracy (km)	ND	3	Sensors/actuators and view directions depend on selection of spin-stabilized or nadir pointing spacecraft. In either case existing guidance and attitude control technology meets mission requirements.
Pointing accuracy (mrad)	ND	3	
Stability (mrad)	ND	3	

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: MERCURY ORBITER AND LANDER P-9

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Power			
Average power consumed (We)	300-600	3, EV	Power source is a Solar Thermoelectric generator (STG) which concentrates solar energy on a thermopile. High temperature solar cell array is alternate.
Peak power consumed (We)	ND	3	
Power breakdown (We)	ND	3	
Energy Storage			
Storage capacity (J)	ND	3, SOA	
Discharge rate (We)	ND	3	Batteries needed during solar occultations. Temperature could be a problem.
Discharge/recharge times (min)	ND	3	
Thermal Control			
Component temperature (K)			
sensors/electronics	275-325	3, EV	Environment is severe due to solar flux about 10 times that at Earth and significant thermal flux from Mercury. Need some innovative methods so that spacecraft is not overly constrained by thermal control requirements.
Component load (Wt) sensors/electronics	ND	3	

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: MERCURY ORBITER AND LANDER P-9

Mission Parameters (units)	Value	Confidence Level, Technology State	Comments
Chemical propulsion			
Total ΔV required (m/sec)	ND	3	
Number of stages	0-2	3	Ballistic mission may need 2 stages; SEPS mission needs one retropropulsion stage. Stage parameters are not determined. SEPS can be used for orbit capture if thermal environment can be tolerated.
First Stage Thrust level(N) Isp (sec) Propellant mass (kg) Inert mass (kg)	ND	3	
Second Stage Thrust level(N) Isp (sec) Propellant mass (kg) Inert mass (kg)	ND	3	
Low-Thrust Propulsion			
Input power (kWe)	ND	3	
Stage mass (kg)	ND	3	SEPS is one option for delivering the spacecraft to Mercury. (Other options are a ballistic trajectory with Venus swingbys and low-thrust trajectories using a solar sail.) Thermal environment may require significant changes in SEPS design
Propellant (kg)	ND	3	
Atmospheric Deceleration			
Entry speed (km/sec)	NA		
Ballistic coefficient (kg/m^2)			
Terminal velocity (m/sec)			

PLANETARY

SENSOR/EXPERIMENT PARAMETERS

MISSION: MERCURY ORBITER AND LANDER P-9

Sensor or Experiment Name	Physical Property Measured/Property Range & Accuracy Resolution	Associated Ranges and/or Resolutions	Purpose, Component Properties, Other Comments
Imaging	Reflected radiance for Mercury	Spectral range of 0.3 to 1.1 μm; resolution of 0.1 μm (3,SOA); spatial resolutions of about 100 m and 1 km	Sensor could be linear array of about 1000 elements or two dimensional array. Used to make global maps and high resolution maps of selected areas. Some in color and/or stereo.
Gamma Ray Spectrometer	Gamma ray emission from material and induced radionuclides; rate is ≈ 10/cm^2/sec; accuracy is limited by background	Energy range of 0-8000 keV and resolution of 2 keV (3,EV); spatial resolution of 250 km (3,SOA) is determined by orbit altitude; long observing time needed	100 cm^3 detector volume (3,EV) of intrinsic germanium; mounted on boom to reduce backgound. Energy resolution by pulse height analysis. Surface elemental composition deduced from observed spectra.
X-ray Fluorescence Spectrometer	X-ray fluorescense excited by solar x-rays interacting with surface of Mercury	Energy range is 0-8 keV and resolution is 0.25 keV (3,SOA) Spatial resolution is 50 km (3,SOA)	Proportional counters (3) with window areas of 50 cm^2 and thickness of 25 μm (2,SOA). Metal filters and pulse height analysis used for energy resolution Surface elemental composition deduced from observed spectra.
Reflectance Spectrometer	Reflected radiance for Mercury with 0.1% resolution	Spectral range of 0.35-2.5 μm and resolution of 0.01 μm; spatial resolution of 2.5 km (3,SOA)	Si diodes and PbS are detectors; PbS cooled to 223 K (3,SOA). Mineralogy deduced from position, strength of spectral absorption features.
Microwave Radiometer	Emitted thermal energy at ≈ 400 K with 0.1 K resolution	Emission measured at 3.6, 10.7 and 20.0 cm; spatial resolution of 250 km (3,SOA)	Internal calibration source. Each band has an antenna with identical beams. Uses IR radiometer to measure surface temperature. Microwave emission gives internal heat flow.

PLANETARY

MISSION: COMET SAMPLE RETURN P-10

Status: Opportunity

Lifetime: 6-7 years Earth departure to Earth return

Launch and Transfer Vehicles: Shuttle/IUS(Twin) plus SEPS

Operational Location: Rendezvous/docking with a comet

Total Mass at Operational Location: 3500 kg (includes SEPS)

Average Operational Power: 30 kw (for SEPS)

OBJECTIVE: It is thought that comets contain the most primitive material in the solar system. Thus it is expected that a comet sample return mission offers a unique opportunity to acquire material that has changed very little since the origin of the solar system. To obtain the types of information desired from a comet sample, it is necessary to study the samples in Earth-based laboratories using many sophisticated techniques.

DESCRIPTION: Current planning guidelines assume that the comet sample return mission is a logical follow-on to Halley Flyby/Tempel 2 Rendezvous (HFTR). In this context, it is an opportunity mission that is not likely to be considered for a new start before 1990. No specific comet has been selected as the mission target. However, for the purpose of evaluating the performance of low-thrust propulsion systems, the periodic comets Encke, Tempel 2 and Honda-Mrkos-Pajudskova have been assumed as candidate mission targets. The comet is encountered about 2 mo. before perihelion and departure is about 3 months after perihelion. Samples of the comet's atmosphere and dust are taken during the 5 mo. stay time. A later departure is needed if a surface sample is to be taken. Sample is returned to Earth orbit for Shuttle retrieval.

CRITICAL TECHNOLOGY NEEDS: Technology requirements are greatly affected by the choice of sample collection methods. If only atmospheric and dust samples are returned, then the requirements are evolutionary relative to HFTR. If a surface sample is brought back, then the mission is much more complex. New technology requirements appear in the sample collection and storage areas. The needs are great for surface samples. There may also be requirements for advanced propulsion systems and for automated rendezvous and dockings.

INSTRUMENT OR EXPERIMENT COMPLEMENT: Sample collection devices
Sample storage devices
Sample documentation equipment (imagery, etc.)

REFERENCES: Lunar and Planetary Missions Handbook, Volume IV
Mission Descriptions (Edition 3) JPL Document No. 710-14, May 1979

CONTACTS: W. C. Wells, Science Applications, Inc., (312)885-6800
R. C. Hastrup, Jet Propulsion Laboratory, (213)354-2253

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: COMET SAMPLE RETURN P-10

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Physical Character			
Overall dimension(m)	70x5x5	3, SOA	
Total Mass (kg)	3000-5000	3, SOA	
Mass breakdown (kg)			
SEPS(low thrust prop)	1200-1800	3, SOA	
Mercury propellant	1200-1800	3, SOA	
Lander/ascent/ Rendezvous vehicle	300-500	3, EV	For surface sample collection only.
Earth return vehicle	50-150	3, EV	Similar to a Mars sample return mission.
Deployed/articulated items, size (m)			
Solar arrays (2)	35x4	3, SOA	For low-thrust propulsion; may include concentrators. Rotate about one axis.
Life			
Flight duration (years)	6	3	
Number of spacecraft	1	3	
Orbit			
Periapse/apoapse altitudes (km)	ND	3	Comet rendezvous is nominally 5 mo.; near comet nucleus operation required for sample collection. Earth return capsule inserted into a 500km periapse orbit with a 24 hr period. Shuttle based transfer vehicle retrieves it.
Inclination (deg)	ND	3	

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: COMET SAMPLE RETURN P-10

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Data			
Data volume (bits/day)	ND	3, SOA	No new technology appears necessary for any data system.
Storage			
Capacity (bits)	ND	3	
I/O rates (kbps)	ND	3	
Spacecraft processors/ computers			
I/O rates (kbps)	ND	3	
Memory size (bits)	ND	3	
Ground Processors/ computers			
Memory size (bits)	ND	3	
Communications			
Minimum/maximum downlink rates (kbps)	ND	3, SOA	Lander data relayed to mission module. Digital data direct to DSN using S-and X-band transmitters. No new technology appears necessary.
Uplink rate (kbps)	ND	3	
Communications distance (AU)	<2.0	3, SOA	During rendezvous.
Guidance & Attitude Control			
View direction	ND	3, SOA	Low-thrust propulsion system is three-axis stabilized using sun, star sensors and gyros. Approach navigation sensor needed to locate/track comet. This sensor determines pointing accuracy/ stability requirements. Above needs are similar to HFTR mission. Actuators are gimbaled science platform and high gain antenna; momentum wheels or thrust vector pointing used on SEPS. Rendezvous with the lander/ascent vehicle which brings sample from surface may require new technology similar to Mars sample return mission.
Position accuracy (km)	ND	3, SOA	
Pointing accuracy (mrad)	ND	3, SOA	
Stability (mrad)	ND	3, SOA	

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: COMET SAMPLE RETURN P-10

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Power			
Average power consumed (We)	ND	3, SOA	Mission module power provided by SEPS. Separate power source for lander/ascent/rendezvous vehicle; type and mission parameters are not determined; technology state expected to be SOA.
Peak power consumed (We)	ND	3	
Power breakdown (We)	ND	3	
Energy Storage			
Storage capacity (J)	ND	3	
Discharge rate (We)	ND	3, SOA	SEPS provides energy storage for many systems. Lander/ascent vehicle may need battery. All technology is SOA.
Discharge/recharge times (min)	ND	3	
Thermal Control			
Component temperature (K)			
Comet samples	≈100	3, EV	Must be kept cold.
LAR	≈283	3, EV	In severe (100°K) environment.
All other	≈283	3, SOA	
Component load (Wt)			
Comet samples	ND	3, EV	
LAR	ND	3, EV	
All other	ND	3, SOA	Depends upon comet perihelion distance.

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: COMET SAMPLE RETURN P-10

Mission Parameters (units)	Value	Confidence Level, Technology State	Comments
Chemical propulsion			
Total ΔV required (m/sec)	ND	3, SOA	
Number of stages	1-2	3	
First Stage			
Thrust level(N)	ND	3	Small liquid propulsion system used to get the lander/ascent vehicle down to comet nucleus surface and return to the main spacecraft.
Isp (sec)	ND	3	
Propellant mass (kg)	ND	3	
Inert mass (kg)	ND	3	
Second Stage			
Thrust level(N)	ND	3	Solid propellant stage used for insertion into earth orbit. Capsule then retrieved by Shuttle-based transfer vehicle. Direct entry or aerobraking eliminate this stage.
Isp (sec)	ND	3	
Propellant mass (kg)	ND	3	
Inert mass (kg)	ND	3	
Low-Thrust Propulsion			
Input power (kWe)	25-60	3, SOA	2:1 solar concentrators may be used. SEPS used for Earth-comet and comet-Earth transfers.
Stage mass (kg)	1200-1800	3, SOA	
Propellant (kg)	1200-1800	3, SOA	
ISP	3000-5000	3, SOA	
Atmospheric Deceleration			
Entry speed (km/sec)	NA		Orbit capture assumption eliminates these; would be needed for direct entry or aerobraking which are available options.
Ballistic coefficient (kg/m^2)			
Terminal velocity (m/sec)			

PLANETARY

SENSOR/EXPERIMENT PARAMETERS

MISSION: COMET SAMPLE RETURN P-10

Sensor or Experiment Name	Physical Property Measured/Property Range & Accuracy Resolution	Associated Ranges and/or Resolutions	Purpose, Component Properties, Other Comments
Sample Analysis	Many different properties	ND	Measurements of returned samples in an Earth-based laboratory using sophisticated and sensitive techniques.
Sample Documentation (lander)	Several different properties	ND	Selected techniques (e.g., imaging, x-ray, γ-ray) to be used in lander documentation of collected samples.
Sample Monitoring	Sample environment	ND	Record sample temperature pressure, radiation exposure after collection.
Remote Sensing (Mission Module)	Several different properties	ND	Imaging, spectrometers used to select the landing site and characterize it relative to the entire comet nucleus.

MISSION: NEAR EARTH ASTEROID SAMPLE RETURN P-11

Status: Opportunity

Lifetime: 3 years Earth departure to Earth return

Launch and Transfer Vehicles: Shuttle/IUS, SEPS optional

Operational Location: Rendezvous/docking with an asteroid

Total Mass at Operational Location: 1000 kg (excludes propulsion)

Average Operational Power: 400 w

OBJECTIVE: An asteroid sample return mission is to provide a surface sample from at least one asteroid. The returned samples would be studied in Earth-based laboratories using the sophisticated techniques used to study meteorites (the objects with which asteroids are often compared). Asteroid samples could provide valuable data on the origin of meteorites and of the solar system. They are also an essential prelude to any program to exploit the near-Earth asteroids for their resources.

DESCRIPTION: Current planning guidelines assume that an asteroid sample return mission follows an asteroid multiple rendezvous mission. Launch of the latter is not expected before 1990, so the sample return mission launch is after 1995. No specific asteroid has been selected as a target. For performance evaluations, herein, Anteros is the assumed target; it is easier to reach than the typical main belt asteroid and is accessible with either SEPS or chemical propulsion. The main spacecraft orbits the asteroid for at least 90 days. A lander/ascent vehicle decends to the surface, collects the sample and then brings the sample back to the main spacecraft. The sample is placed in a return capsule which after the return trip to Earth is placed into Earth orbit for retrieval by a Shuttle-based transfer vehicle.

CRITICAL TECHNOLOGY NEEDS: Technology requirements are closely related to sample collection methods. Acquiring samples at more than one site per asteroid increases requirements for all lander/ascent vehicle systems. Samples from difficult materials (metals?), large samples and documentation increase requirements for sampling systems.

INSTRUMENT OR EXPERIMENT COMPLEMENT: Sample collection devices, storage devices and documentation equipment (imagery, etc.).

REFERENCES: Asteroid Mission Study, Science Applications, Inc., Report No. 1-120-839-M11, May 1979.

CONTACTS: W. C. Wells, Science Applications, Inc., (312)885-6800

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: NEAR EARTH ASTEROID SAMPLE RETURN P-11

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Physical Character			
Overall dimension(m)	70x5x5	3, SOA	Smaller without SEPS.
Total Mass (kg)			
Mass breakdown (kg)	3000-5000	3, SOA	
SEPS(low-thrust prop)	1200-1800	3, SOA	
Mercury propellant	1200-1800	3, SOA	
Lander/ascent/rendezvous vehicle	300-500	3, EV	Similar to a Mars sample return mission (1.0 kg sample).
Earth return vehicle	50-150	3, EV	
Deployed/articulated items, size (m)			
Solar Arrays(2)	30x4	3, SOA	For low-thrust propulsion; rotate about one axis.
Life			
Flight duration (years)	3-4	3	
Number of spacecraft	1	3	
Orbit			
Periapse/apoapse altitudes (km)	ND	3	Asteroid rendezvous is 3 mo. minimum; during rendezvous phase, main spacecraft orbits asteroid and lander/ascent vehicle descends to surface to collect sample and then returns to main spacecraft.
Inclination (deg)	ND	3	

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: NEAR EARTH ASTEROID SAMPLE RETURN P-11

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Data			
Data volume (bits/day)	ND	3, SOA	No new technology appears necessary for any data system.
Storage			
Capacity (bits)	ND	3, SOA	
I/O rates (kbps)	ND	3, SOA	
Spacecraft processors/ computers			
I/O rates (kbps)	ND	3, SOA	
Memory size (bits)	ND	3, SOA	
Ground Processors/ computers			
Memory size (bits)	ND	3, SOA	
Communications			
Minimum/maximum downlink rates (kbps)	ND	3, SOA	Lander data relayed via main spacecraft. Spacecraft data is digital, transmitted to DSN using S-and X-bands. No new technology appears necessary.
Uplink rate (kbps)	ND	3, SOA	
Communications distance (AU)	<5.0	3, SOA	During rendezvous and cruise.
Guidance & Attitude Control			
View direction	ND	3, SOA	Low-thrust propulsion system is three-axis stabilized using sun, star sensors and gyros. Approach navigation sensor needed to locate track asteroid. This sensor determines pointing accuracy/stability requirements. Above needs are similar to HFTR mission. SEPS has momemtum wheels and thrust vector pointing for attitude control. Science platform and high-gain antenna are articulated. Rendezvous with the lander/ascent vehicle which brings sample from surface may require new technology similar to Mars sample return mission.
Position accuracy (km)	ND		
Pointing accuracy (mrad)	ND		
Stability (mrad)	ND		

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: NEAR EARTH ASTEROID SAMPLE RETURN P-11

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Power			
Average power consumed (We)	ND	3, SOA	SEPS provides power from its solar cells. Separate power source for lander/ascent/rendezvous vehicle; type and mission parameters are not determined; technology state expected to be SOA.
Peak power consumed (We)	ND	3, SOA	
Power breakdown (We)	ND	3, SOA	
Energy Storage			
Storage capacity (J)	ND	3, SOA	SEPS provides energy storage. Lander/ascent vehicle may need batteries.
Discharge rate (We)	ND	3, SOA	
Discharge/recharge times (min)	ND	3, SOA	
Thermal Control			
Component temperature (K)			
Asteroid samples	150	3, EV	
Lander/ascent/rend.	283	3, EV	May operate in severe environments (both hot and cold).
All others	283	3, SOA	
Component load (Wt)			
Asteroid samples	ND	3, EV	
LAR	ND	3, EV	
All other	ND	3, SOA	

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: NEAR EARTH ASTEROID SAMPLE RETURN P-11

Mission Parameters (units)	Value	Confidence Level, Technology State	Comments
Chemical propulsion			
Total ΔV required (m/sec)	ND	3, SOA	See Comet sample return for Earth return vehicle propulsion requirements.
Number of stages	1-4	3	
First Stage			
Thrust level(N)	ND	3, SOA	Liquid propulsion system to get lander/ascent vehicle down to asteroid surface and return with samples to main spacecraft (requirement is 700 m/sec for Vesta, less for smaller near-Earth Asteroids).
Isp (sec)	ND		
Propellant mass (kg)	ND	3	
Inert mass (kg)	ND		
Second Stage			
Thrust level(N)	ND	3, SOA	
Isp (sec)	ND	3	
Propellant mass (kg)	ND	3	One (or two) stages required for asteroid rendezvous and departure. ΔV's are large (2.7km/sec for Anteros mission in 1992 and larger for other asteroids).
Inert mass (kg)	ND	3	
Low-Thrust Propulsion			
Input power (kWe)	20-40	3, SOA	SEPS is an alternative to large propulsion stages for Earth-asteroid and asteroid-Earth trajectories.
Stage mass (kg)	1200-1800	3	
Propellant (kg)	1200-1800	3	
Atmospheric Deceleration			
Entry speed (km/sec)	NA	3	Not needed because orbit capture at Earth is assumed; would be needed for direct entry or aerobraking which are available options.
Ballistic coefficient (kg/m^2)			
Terminal velocity (m/sec)			

PLANETARY

SENSOR/EXPERIMENT PARAMETERS

MISSION: NEAR EARTH ASTEROID SAMPLE RETURN P-11

Sensor or Experiment Name	Physical Property Measured/Property Range & Accuracy Resolution	Associated Ranges and/or Resolutions	Purpose, Component Properties, Other Comments
Sample Analysis	Many different properties	ND	Measurements of returned samples in an Earth-based laboratory using sophisticated and sensitive techniques.
Sample Documentation (lander)	Several different properties	ND	Selected techniques (e.g., imaging, x-ray, γ-ray) to be used on lander for documentation of collected samples.
Sample Monitoring	Sample Environment	ND	Record sample temperature, pressure, radiation exposure after collection.
Remote Sensing (Mission module)	Several different properties	ND	Imaging, spectrometers used to select the landing site and characterize it relative to the entire asteroid.

MISSION: VENUS LANDER P-12

Status: Opportunity

Lifetime: 6 mos. (Earth-Venus flighttime)

Launch and Transfer Vehicles: Shuttle/IUS

Operational Location: Venus surface for several hours to days

Total Mass at Operational Location: 550 kg

Average Operational Power: 65w

OBJECTIVE: The objective of the mission is the in-situ investigation of local surface areas and the interior areas of Venus. Local investigation would include surface geology, geochemistry, goephysical properties and meteorology. This mission could include landings at multiple sites selected on the basis of data from the Venus Orbital Imaging Radar (VOIR) mission. Atmospheric measurements could be made from ballons being developed in France.

DESCRIPTION: This mission is considered for the post-VOIR time-frame and, consequently, is not well defined. The mission might consist of several survivable probes and/or a larger capsule probe. The smaller probes would have to perform their measurements in about one hour. The larger probe might remain active for one day. This description concentrates on the larger capsule as it has more demanding requirements. A sample return mission is an alternative method for intensive Venus exploration.

CRITICAL TECHNOLOGY NEEDS: The high temperature/pressure environment at the surface of Venus has a major impact on all lander systems including the instrumentation.

INSTRUMENT OR EXPERIMENT COMPLEMENT: Example payload includes multispectral imager, in-situ instruments to determine soil composition and mineorology, geophysical experiments such as seismometry and electromagnetic sounding and a meteorological sensor for temperature, pressure and wind velocity.

REFERENCES: "Future Exploration of Venus"(Post-Pioneer Venus 1978)
NASA TM-X-62450, Ames Research Center, January 1976.

CONTACTS: J. Murphy, ARC, (415)965-6520

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: VENUS LANDER P-12

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Physical Character			
Overall dimension(m)	2x1.1 (dia)	3, SOA	
Total Mass (kg)	550	3	Small probes are 120 kg; flyby bus is 300 kg.
Mass breakdown (kg)			
Science	30	3	
Batteries	60	3	Includes 15 kg electronics
Thermal control	175	3	Insulation, phase change material
Structure	100	3	Pressure vessel (1.1m dia.)
Aeroshell	180	3	
Deployed/articulated items, size (m)	ND	3	
Life			
Flight duration (years)	0.5	3	Large lander spends one day on surface.
Number of spacecraft	1	3	One large lander; three small probes and one flyby bus.
Orbit			
Periapse/apoapse altitudes (km)	NA		Landing locations to be selected using VOIR data; Direct entry after deployment from flyby bus.
Inclination (deg)			

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: VENUS LANDER P-12

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Data			
Data volume (bits/day)	$2x10^8$	3, SOA	
Storage			
Capacity (bits)	ND	3, SOA	Small memory to store entry descent, and landing data.
I/O rates (kbps)	ND	3	
Spacecraft processors/ computers			
I/O rates (kbps)	ND	3, SOA	Small and simple; high temperature capability
Memory size (bits)	ND	3	
Ground Processors/ computers			
Memory size (bits)	ND	3	Existing systems used.
Communications			
Minimum/maximum downlink rates (kbps)	2	3, SOA	Digital data sent direct to DSN at S-band frequency for tracking.
Uplink rate (kbps)	ND	3	
Guidance & Attitude Control			
View direction	NA		
Position accuracy (km)	NA	3	Probe is spin stabilized between deployment and entry.
Pointing accuracy (mrad)	NA		
Stability (mrad)	NA		

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: VENUS LANDER P-12

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Power			
Average power consumed (We)	65	3, SOA	Batteries (silver-zinc)
Peak power consumed (We)	72	3	
Power breakdown (We)			
Science	33	3	
Electronics	39	3	
Energy Storage			
Storage capacity (J)	6×10^6	3	Ag-Zn batteries deliver about 65w for one day.
Discharge rate (We)	65	3	
Discharge/recharge times (min)	1440/NA	3	
Thermal Control			
Component temperature (K)			
Internal Electronics	<395		Temperature of internal electronics maintained at less than 395K for one day by extensive insulation and phase change material. External mechanisms exposed to very high temperatures.
External Mechanisms	≈700		
Component load (Wt)			
Internal Electronics	ND		
External Mechanisms	NA		

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: VENUS LANDER P-12

Mission Parameters (units)	Value	Confidence Level, Technology State	Comments
Chemical propulsion			
Total ΔV required (m/sec)	Small	3, SOA	Flyby bus has small liquid propulsion system for trajectory corrections.
Number of stages	1		
First Stage			
Thrust level(N)	ND		
Isp (sec)	ND		
Propellant mass (kg)	ND		
Inert mass (kg)	ND		
Second Stage			
Thrust level(N)			
Isp (sec)			
Propellant mass (kg)			
Inert mass (kg)			
Low-Thrust Propulsion			
Input power (kWe)	NA		
Stage mass (kg)			
Propellant (kg)			
Atmospheric Deceleration			
Entry speed (km/sec)	ND		Probe enters atmosphere after deployment by bus. Conical aeroshell retained until just before landing. Parachute used to reduce impact speed.
Ballistic coefficient (kg/m^2)	ND		
Terminal velocity (m/sec)	ND		

PLANETARY

SENSOR/EXPERIMENT PARAMETERS

MISSION: VENUS LANDER

Sensor or Experiment Name	Physical Property Measured/Property Range & Accuracy Resolution	Associated Ranges and/or Resolutions	Purpose, Component Properties, Other Comments
Imaging	Reflected radiance from Venus	Spectral ranges of 0.3 to 1.1μm and resolution of 0.1μm (3,SOA); angular resolution of about 1 mrad (3,SOA); coverage of entire surface near lander (3,EV).	Study soil texture, surface morphology and lander orientation. Heat flow through windows may limit coverage. External articulated mirror desired. Light source may be needed.
X-ray/γ-ray Spectroscopy	Surface composition of major elements (>1%) with about 10% resolution.	ND	Look for evidence of rock differentation, surface weathering. γ-ray is internal; x-ray sensor is external(i.e., high temperature) or needs collected sample.
Reflectance Spectroscopy	Reflected radiance from Venus	Spectral range 0.36 to 2.5μm resolution of 0.01 μm (3,SOA)	Study rock types and state of oxidation by depth/position of absorption bands. Same problems as imaging.
Meteorology	Wind velocity, (<10m/sec) pressure (<100 atm) temperature (<800 K)	ND	Important for understanding aeolian processes.
Active Seismometry	Transmission velocity of seismic waves in Venus soil	ND	Difficult experiment because active charges are used. The Venus environment is a problem as is determining time, location of explosion.

MISSION: AUTOMATED MOBILE LUNAR SURFACE SURVEY P-13

Status: Opportunity

Lifetime: Several months to a few years on lunar surface

Launch and Transfer Vehicles: Shuttle/IUS(Twin)

Operational Location: Lunar surface (possibly polar region)

Total Mass at Operational Location: 250-750kg

Average Operational Power: 150-400w

OBJECTIVE: The objective of this mission is to make a detailed survey of the lunar surface to determine surface chemical and physical characteristics and to search for resources.

DESCRIPTION: Mission originally proposed as Apollo follow-on and as precursor to Mars rover. Also needed to evaluate Moon as source of material for space industrialization. Roving vehicles would be landed in areas of interest on the Moon. Detailed in-situ science would be performed at selected sites. Multiple landers might provide an alternative but would allow much less flexibility. The automated lunar rover is assumed to be similar to vehicles being studies for missions to Mars. Autonomous operation in the areas of path planning and power control allow the rover to operate effectively with only major decisions for path and science operations made by mission controllers. This mode is necessary for exploring polar regions.

CRITICAL TECHNOLOGY NEEDS: Autonomous rover guidance capability. Improved analytical instruments.

INSTRUMENT OR EXPERIMENT COMPLEMENT: Sample acquisition, documentation equipment. Geochemical and Geophysical analysis instruments, including imaging.

REFERENCES: None. However, some references for Mars Advanced Technology (Sample Return) program apply.

CONTACTS: J. French, JPL, (213)354-5602
G. Paine, JPL, (213)354-4047

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: AUTOMATED MOBILE LUNAR SURFACE SURVEY P-13

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Physical Character			
Overall dimension(m)	1.5x0.8 x1.0	2, SOA	Based upon Mars Rover
Total Mass (kg)	250-750	2, EV	
Mass breakdown (kg)	ND		
Deployed/articulated items, size (m)	ND		
Life			
Flight duration (years)	0.5-3.0	3, EV	
Number of spacecraft	1		
Orbit			
Periapse/apoapse altitudes (km)	NA		May require polar orbiting relay for exploring polar regions.
Inclination (deg)	NA		

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: AUTOMATED MOBILE LUNAR SURFACE SURVEY P-13

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Data			
Data volume (bits/day)	10^9	2, SOA	Based on Mars Rover
Storage			
Capacity (bits)	10^9	2, SOA	Digital tape recorder used if not in line of sight of Earth (especially polar regions).
I/O rates (kbps)	ND	2, SOA	
Spacecraft processors/ computers			
I/O rates (kbps)	ND	2, EV	For acquiring/processing data used by automated guidance system; I/O rates, memory and speed requirements are moderate to high.
Memory size (bits)	ND	2, EV	
Ground Processors/ computers			
Memory size (bits)	ND		Not critical with autonomous operation.
Communications			
Minimum/maximum downlink rates (kbps)	ND		Either direct to DSN or relay through satellite in lunar orbit or libration point to DSN. Data is assumed to be digital signal on S- or X-band frequency.
Uplink rate (kbps)	ND		
Guidance & Attitude Control			
View direction	360°	2	
Position accuracy (km)	Varies	2, EV	Few cm at range of 1-2m. 1 or 2 cm at 100m range. Laser triangulation and/or video scene analysis required for path planning.
Pointing accuracy (mrad)	ND		
Stability (mrad)	NA		

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: AUTOMATED MOBILE LUNAR SURFACE SURVEY P-13

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Power			
Average power consumed (We)	150-400	2, EV	Radioisotope thermal generator (RTG). Possibly supplemented by solar photovoltaic. Depends upon instrument load and desired traverse rate.
Peak power consumed (We)	ND		
Power breakdown (We)	ND		
Energy Storage			
Storage capacity (J)	NA		Probably not required for RTG powered rover unless there are peak load requirements.
Discharge rate (We)	ND		
Discharge/recharge times (min)	ND		
Thermal Control			
Component temperature (K)			
Electronics/Sensors	ND	3, SOA	Use heat pipes to transfer heat from RTG to radiators and into chassis for thermal control.
Component load (Wt)			
Electronics/Sensors	ND		

MISSION TECHNOLOGY REQUIREMENTS

MISSION: AUTOMATED MOBILE LUNAR SURFACE SURVEY P-13

Mission Parameters (units)	Value	Confidence Level, Technology State	Comments
Chemical propulsion			
Total ΔV required (m/sec)	ND	3, SOA	Propulsion will be required to place the vehicle on the lunar surface and to place a relay satellite (if used) in orbit.
Number of stages	2-3	3, SOA	
First Stage			
Thrust level(N)	ND		
Isp (sec)	ND		
Propellant mass (kg)	ND		
Inert mass (kg)	ND		
Second Stage			
Thrust level(N)	ND		
Isp (sec)	ND		
Propellant mass (kg)	ND		
Inert mass (kg)	ND		
Low-Thrust Propulsion			
Input power (kWe)	NA		
Stage mass (kg)			
Propellant (kg)			
Atmospheric Deceleration			
Entry speed (km/sec)	NA		
Ballistic coefficient (kg/m^2)			
Terminal velocity (m/sec)			

PLANETARY

SENSOR/EXPERIMENT PARAMETERS

MISSION: AUTOMATED MOBILE LUNAR SURFACE SURVEY P-13

Sensor or Experiment Name	Physical Property Measured/Property Range & Accuracy Resolution	Associated Ranges and/or Resolutions	Purpose, Component Properties, Other Comments
Bulk Chemistry	Major element (>1%) chemical composition of lunar soil with 5 to 10% resolution.	ND	Define geologic units; find major resources. Use pulsed neutrons, x-rays and/or α-particles to excite atoms/nuclei. (3,SOA)
Trace Element Chemistry	Minor (<1%) and trace ($<10^4$ parts) elements chemical composition of lunar soil with 10 to 30% resolution.	ND	Abundances of minor and trace elements are used to study chemical differentiation (e.g., volcanism). Use scanning electron and/or ion microprobe. Must be able to identify element concentrations in bulk material and in specific mineral grains. (3,EV).
Age-dating	Isotope ratios of specific elements	ND	Determine age of sample and date geologic events. Use scanning ion microprobe with mass analyzer for isotopic determination. (3, REV).
Crystal Structure	Mineral Abundances	ND	Important for resource survey and for studies of conditions present during control evolution. Instruments are x-ray diffractometer and a petrographic microscope. (3, EV).
Geophysical Analysis	Many different properties	ND	Imagery, magnetometery, active seismometery and electromagnetic sounding to explore local geologic structure. (3, SOA).

PLANETARY

MISSION: AUTOMATED PLANETARY STATION P-14

Status: Opportunity

Lifetime: 5 years to end of mission

Launch and Transfer Vehicles: Shuttle

Operational Location: Low Earth orbit

Total Mass at Operational Location: 25,000 kg

Average Operational Power: 25kw

OBJECTIVE: Planetary observations are to be made from an orbiting platform. Continuous observations of dynamic phenomena (e.g., atmospheres) are possible. Emphasis will be on wavelengths that cannot be observed with Earth-based telescopes; on the use of interferometers with 0.01 arc sec angular resolutions that cannot be attained when viewing through the Earth's atmosphere, and on new measurement techniques for deep space missions.

DESCRIPTION: A 25kw power module provides the basic support functions for this mission. The power module provides power, altitude control, and communications. Instruments are placed on pallets (similar to Spacelab) and may be either relatively small principal investigator experiments or large multi-user facilities. Shuttle revisits could be utilized for replentishing consumables (e.g., film, cryogenic liquids), maintenance and for recovery of the pallet and its instrumentation. Earliest possible launch date is 1990. Consequently little effort has been expended studying this opportunity.

CRITICAL TECHNOLOGY NEEDS: New technology needed for science instruments and pointing systems to meet goal of 0.01 arc sec. for angular resolution. This may include extensive on-board data processing of interferometer data.

INSTRUMENT OR EXPERIMENT COMPLEMENT: A few large multi-user facilities for high-resolution observations of planets in reflected, solar illumination and thermal emission and any smaller principal investigator size instruments not yet defined.

REFERENCES: None.

CONTACTS: W. C. Wells, Science Applications, Inc. (312)885-6800

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: AUTOMATED PLANETARY STATION P-14

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Physical Character			
Overall dimension(m)	80x15x9	3, EV	
Total Mass (kg)	25,000	3, SOA	
Mass breakdown (kg)			
Power Module	13,000		
Deployed/articulated items, size (m)			
Solar Arrays(2)	35x4	3, SOA	
Life			
Flight duration (years)	5-10	3, SOA	Shuttle revisits about once per year for resupply, repair and instrument changeouts.
Number of spacecraft	1		
Orbit			
Periapse/apoapse altitudes (km)	300-600	3	
Inclination (deg)	ND	3	

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: AUTOMATED PLANETARY STATION P-14

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Data			
Data volume (bits/day)	10^{11}	3, SOA	Data volume per planet similar to an orbiter mission; assumes significant on-board processing. Large capacity ($\approx 10^{10}$) and high I/O rates ($\approx$100 MHz) desired.
Storage			
Capacity (bits)	ND	3, SOA	
I/O rates (kbps)	ND	3, SOA	
Spacecraft processors/ computers			
I/O rates (kbps)	ND	3, EV	Large, fast on-board computer desired for controlling interferometer data and processing their data.
Memory size (bits)	10^9	3, EV	
Ground Processors/ computers			
Memory size (bits)	ND	3, EV	
Communications			
Minimum/maximum downlink rates (kbps)	10^5	3, SOA	Use TDRSS K_u band single access channel for science data.
Uplink rate (kbps)	ND	3, SOA	
Guidance & Attitude Control			
View direction	celestial	3	Three-axis stabilized; basic capability provided by power module.
Position accuracy (km)	ND	3	
Pointing accuracy (mrad)	ND	3	
Stability (mrad)	5×10^{-5}	3, REV	Corresponds to 0.01 arc sec.

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: AUTOMATED PLANETARY STATION P-14

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Power			
Average power consumed (We)	25	3, SOA	Power module has solar cells.
Peak power consumed (We)	ND	3	
Power breakdown (We)	ND		
Energy Storage			
Storage capacity (J)	ND	3	Large energy storage capability is needed unless orbit is always in sunlight.
Discharge rate (We)	ND	3	
Discharge/recharge times (min)	ND	3	
Thermal Control			
Component temperature (K)			
Electronics	280	3	Actively cooled sensors are very likely. Some structural element must be controlled to maintain optical alignments needed for 0.01 arc sec resolution.
Sensors	ND		
Structure	ND		
Component load (Wt)			
Electronics	ND	3	
Sensors	ND		
Structure	ND		

MISSION TECHNOLOGY REQUIREMENTS

MISSION: AUTOMATED PLANETARY STATION P-14

Mission Parameters (units)	Value	Confidence Level, Technology State	Comments
Chemical propulsion			
Total ΔV required (m/sec)	ND	3	Small backup for altitude control system. Larger system useful for altitude adjustments.
Number of stages	1	3	
First Stage			
Thrust level(N)	ND	3	
Isp (sec)	ND	3	
Propellant mass (kg)	ND	3	
Inert mass (kg)	ND	3	
Second Stage			
Thrust level(N)	NA		
Isp (sec)			
Propellant mass (kg)			
Inert mass (kg)			
Low-Thrust Propulsion			
Input power (kWe)	NA		
Stage mass (kg)			
Propellant (kg)			
Atmospheric Deceleration			
Entry speed (km/sec)	NA		
Ballistic coefficient (kg/m^2)			
Terminal velocity (m/sec)			

PLANETARY

SENSOR/EXPERIMENT PARAMETERS

MISSION: AUTOMATED PLANETARY STATION P-14

Sensor or Experiment Name	Physical Property Measured/Property Range & Accuracy Resolution	Associated Ranges and/or Resolutions	Purpose, Component Properties, Other Comments
Optical Interferometer	Reflected radiance from planetary objects	Spectral range of 0.3 to 1.1μm with resolution of 0.01μm (3,EV). Angular resolution of 0.01 arc sec (3,REV)	Sensors not defined. Used to obtain very high resolution images of solar system bodies for studies of atmospheric structure/dynamics.
UV/Optical/IR Telescope	Reflected radiance from planetary objects	Spectral range of 0.1 to 3μm with resolution of 10^{-2} to 10^{-5}μm (3,EV) Angular resolution of 0.1 arc sec (3,EV)	Sensors not defined. Used to observe spectrum of reflected light from solar system bodies and to infer atmospheric structure/composition and/or surface composition.
Infrared Interferometer	Thermal emission from planetary objects	Spectral range of 5 to 30μm (3,EV). Angular resolution of 0.1 arc sec (3,REV)	Sensors not defined. High resolution thermal imagery used for studies of atmospheres.
Infrared Telescope	Thermal emission from planetary objects	Spectral range of 5μm to 1 mm; (3,EV). Angular resolution of 1 arc sec at 20μm (3,EV)	Sensors not defined. Used to obtain accurate temperatures and emission spectra for solar system bodies and to infer atmospheric structure/composition and/or surface composition/physical properties.

MISSION: LUNAR BACKSIDE LANDER AND SAMPLE RETURN P-15

Status: Opportunity

Lifetime: 2-4 weeks (launch to sample return)

Launch and Transfer Vehicles: Not determined

Operational Location: Lunar surface (backside)

Total Mass at Operational Location: Not determined

Average Operational Power: Not determined

OBJECTIVE: This mission obtains a surface sample from the backside of the Moon. It is known that the lunar backside is different from the near side (e.g., it lacks mare) from which all previous samples were taken. Samples are to be examined in Earth-based laboratories.

DESCRIPTION: A cooperative US-USSR mission is envisioned using the Soviet sample return vehicle and the Lunar Polar Orbiter (LPO) spacecraft as a relay for communications. The Soviet vehicle requires a vertical takeoff and it has been determined that this is compatible with far side landing sites.

CRITICAL TECHNOLOGY NEEDS: This mission would be performed only if the proposed spacecraft can be used with few modifications. Detailed description of technolgoy requirements is not given for this mission. (Note that the LPO mission has been described)

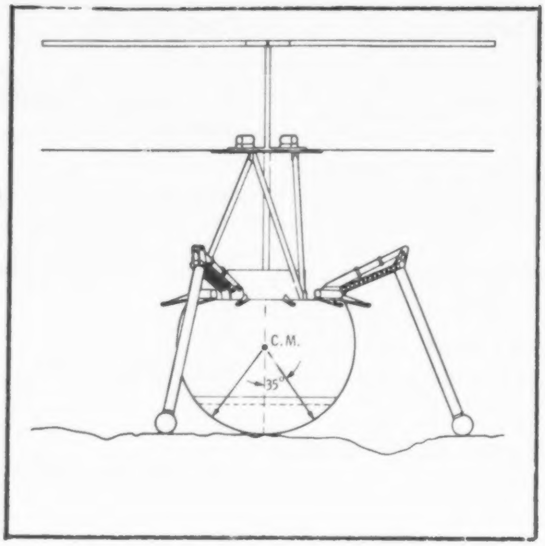
INSTRUMENT OR EXPERIMENT COMPLEMENT: Not determined for lander.

REFERENCES: None. See references for Lunar Polar Orbiter.

CONTACTS: P. H. Roberts, Jr., JPL, (213)354-5513

MISSION: GANYMEDE LANDER P-16

Status:	Opportunity
Lifetime:	8 years (launch to end-of-mission)
Launch and Transfer Vehicles:	Shuttle/IUS(Twin/Spinner)
Operational Location:	Surface of Ganymede (Satellite of Jupiter)
Total Mass at Operational Location:	75kg (approx.)
Average Operational Power:	5-10w



OBJECTIVE: The objective of the Ganymede Lander mission is to deploy a semi-hard lander vehicle on the surface of this Galilean satellite of Jupiter. The lander makes in-situ geophysical and geochemical observations of Ganymede (including images of the satellite surface) and could make synoptic observations of Jupiter's atmosphere, too.

DESCRIPTION: This mission is being considered as a Galileo follow-on. Basic mission profile is very similar to Galileo, but with gravity assists at Callisto and Ganymede being used to establish a near-Hohman transfer between these two satellites for Lander deployment. On the orbit prior to the final encounter with Ganymede the lander is separated from the orbiter. The lander performs retro and terminal braking maneuvers which result in a semi-hard landing. The lander then prepares for surface operations. Requirements for the orbiter spacecraft are similar to Galileo. An alternative is the surface penetrator.

CRITICAL TECHNOLOGY NEEDS: The lander vehicle, especially the radar altimeter and doppler radar needed to effect the landing. Lander must survive up to 300 g's shock from landing. Jupiter's radiation belts could be a problem.

INSTRUMENT OR EXPERIMENT COMPLEMENT: A small imaging system, other geochemical/ geophysical instruments are to be selected. Orbiter instruments would be similar to Galileo.

REFERENCES: Boain, R.J. and Bekcman, J.C., "A Ganymede Lander Mission, AAS/AIAA Astrodynamics Specialist Conference, June 25-27, 1979.

CONTACTS: R. J. Boain, JPL, (213)354-2947

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: GANYMEDE LANDER P-16

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Physical Character			
Overall dimension(m)	1 dia	3	
Total Mass (kg)	65	3	Includes 11 kg for science.
Mass breakdown (kg)	ND		
Deployed/articulated items, size (m)			
Antenna	1-2	3	
Life			
Flight duration (years)	ND	3	Duration of lifetime on surface and Earth-Jupiter trajectory are not determined. About one year needed between Jupiter deployment for purpose of establishing deployment orbit.
Number of spacecraft	1		
Orbit			
Periapse/apoapse altitudes (km)	Varies	3	Satellite flybys used to establish spacecraft orbit around Jupiter for lander deployment with periapse near Ganymede's orbit, apoapse near Callisto's and phased for Ganymede encounter.
Inclination (deg)	ND	3	

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: GANYMEDE LANDER P-16

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Data			
Data volume (bits/day)	ND	3	
Storage			
Capacity (bits)	ND	3	Depends upon communications capability.
I/O rates (kbps)	ND	3	
Spacecraft processors/ computers			
I/O rates (kbps)	ND	3	
Memory size (bits)	ND	3	Must be kept small and simple.
Ground Processors/ computers			
Memory size (bits)	ND	3	Use existing capabilities.
Communications			
Minimum/maximum downlink rates (kbps)	ND	3	Direct digital link with the DSN low data rate and/or higher rate link via orbiter.
Uplink rate (kbps)	ND	3	
Guidance & Attitude Control			
View direction	ND	3	Radar altimeter needed to measure lander altitude and command retro maneuver ignition at ≈75Km above the surface. Attitude during retro maneuver must be with 0.7° (3σ)of nominal. Three axis stabilization for hard landing at ≤ 22 m/sec.
Position accuracy (km)	TBD	3	
Pointing accuracy (mrad)	ND	3	
Stability (mrad)	ND	3	

MISSION TECHNOLOGY REQUIREMENTS

MISSION: GANYMEDE LANDER P-16

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Power			
Average power consumed (We)	5-10	3	Radioisotope thermal generator is most likely power source.
Peak power consumed (We)	ND	3	
Power breakdown (We)	ND	3	
Energy Storage			
Storage capacity (J)	NA		Assuming RTG power.
Discharge rate (We)			
Discharge/recharge times (min)			
Thermal Control			
Component temperature (K)			
Electronics/sensors	275	3	Surface is cold; keep electronics warm with internal dissipation plus some RTG heat. Experiments may have high/low temperature requirements.
Component load (Wt)			
Electronics/sensors	ND	3	

PLANETARY

MISSION TECHNOLOGY REQUIREMENTS

MISSION: GANYMEDE LANDER P-16

Mission Parameters (units)	Value	Confidence Level, Technology State	Comments
Chemical propulsion			
Total ΔV required (m/sec)	3540	3	
Number of stages	2	3	
First Stage			
Thrust level(N)	18523	3	Large solid propellant stage for retro maneuver (3420 m/s)
Isp (sec)	282	3	
Propellant mass (kg)	ND	3	
Inert mass (kg)	ND	3	
Second Stage			
Thrust level(N)	4640	3	Small solid propellant stage for terminal braking maneuver (124 m/s)
Isp (sec)	275	3	
Propellant mass (kg)	ND	3	
Inert mass (kg)	ND	3	
Low-Thrust Propulsion			
Input power (kWe)	NA		
Stage mass (kg)			
Propellant (kg)			
Atmospheric Deceleration			
Entry speed (km/sec)	NA		
Ballistic coefficient (kg/m^2)			
Terminal velocity (m/sec)			

PLANETARY

SENSOR/EXPERIMENT PARAMETERS

MISSION: GANYMEDE LANDER

Sensor or Experiment Name	Physical Property Measured/Property Range & Accuracy Resolution	Associated Ranges and/or Resolutions	Purpose, Component Properties, Other Comments
Imaging	Reflected radiance for satellite surface	Spectral range of 0.3 to 1.1μm(3,SOA); Angular resolution of about 1 mrad (3,SOA). 360° coverage	Imagery used for site characterization in terms of soil texture, local geologic processes, etc. Facsimile camera (Viking) or frame cameras using CCD array detectors.
Geochemical Analysis	Major element (>1%) chemical composition of satellite surface with 10-20% resolution	ND	X-ray fluorescence, and α-scattering. Also water detection by analysis of chemical reactions and/or response to heating.
Geophysical Analysis	Several different properties	ND	Seismometery/accelerometer to look at local subsurface geologic structure. Magnetometer. Thermocouples for heat flow and thermal conductivity.

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ASTROPHYSICS

The Astrophysics program strategy is first to identify sources and new phenomena; then to catalog sources by making "all sky" surveys in appropriate wavelengths; then to study identified sources with high-resolution observatories; and then finally to make correlative studies of the sources in all appropriate wavelengths in order to develop a complete understanding of the phenomena and objectives involved. In addition to investigations of electromagnetic and particle radiation, research is to be conducted in relativity, gravitation, and other relevant physical areas.

The basic techniques used in astrophysics are imaging, spectrometry, photometry, and polarimetry. Current efforts are performed in low earth orbit and are most advanced in the "classical" regions of the spectrum (visible and IR) due to the extensive ground-based historical studies. A primary focus of this program is in those parts of the spectrum obscured by the earth's atmosphere, such as gamma rays, X-rays, the ultraviolet, and much of the IR and radio region, where space-based measurements are essential.

In order to progress from the small, specialized astrophysics spacecraft of today to the large multi-instrument spacecraft of the future, a bootstrap approach is being considered. This would entail shifting Shuttle-mounted instrumentation to Shuttle-tended free-flyers or large multi-instrument platforms.

ASTROPHYSICS MISSIONS

No.	
A-18	Infrared Interferometer will make observations of the physical sources in galactic cores, the dynamics of stellar formation, and the interaction of gas and radiation in planetary nebulae.
A-19	Gravity Wave Interferometer searches for gravitational radiation from astrophysical sources such as binaries, pulsars, and black holes.
A-20	Coherent Optical System of Modular Imaging Collectors would provide a significant increase in resolution over the space telescope presently under development.
A-21	Large Optical/UV Telescope, Diffraction Limited would provide a tenfold increase in sensitivity over the space telescope presently under development.
A-22	100-m Thinned Aperture Telescope has as its basic objective a 30-fold increase in image resolution and a 1000-fold increase in astrometric precision over that afforded by the space telescope.

ASTROPHYSICS
MISSION: INFRARED INTERFEROMETER A-18

Status: Opportunity

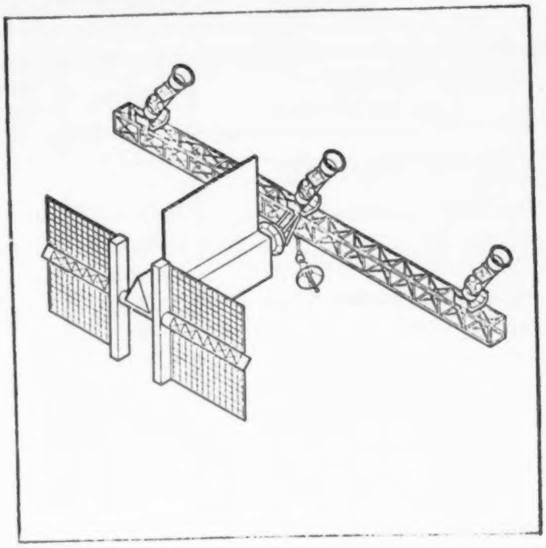
Lifetime: 5 years useful life

Launch and Transfer Vehicles: Shuttle

Operational Location: Earth orbit at an altitude of 400 to 700 km

Total Mass at Operational Location: 22,500 kg

Average Operational Power: Not determined; 25 kw is available.



OBJECTIVE: An infrared interferometer is able to make observations with higher angular resolution than a single mirror telescope. High resolution studies of galactic nuclei, protostars, young stellar objects, circumstellar shells and binary systems are intended to elucidate the physical processes in galactic cores, the dynamics of stellar formation and the interaction of gas and radiation in planetary nebulae.

DESCRIPTION: Three cooled IR telescopes are positioned on a 100 m deploy able boom to form a sensitive interferometer. Two telescopes have movement capability along the baseline to change separation distance. Operations commence after the boom is deployed and the telescopes are locked in their vertical viewing position. Engineering support is provided by a Science and Space Applications Platform. Data is transmitted via TDRSS to the ground science team. Annual Shuttle revisits are used to replenish cryogens; a five-year mission permits study of a significant number of astronomical objects. Other options to be evaluated are two element interferometers using one Shuttle-based telescope and one free-flying telescope or large ambient-temperature telescopes in place of the cooled IR telescopes. Concept needs further study and demonstrations of the preferred options.

CRITICAL TECHNOLOGY NEEDS: Active control of interferometer element spacings and orientations, attitude stability, cryogenic cooling of large systems, interferometric signal detection.

INSTRUMENT OR EXPERIMENT COMPLEMENT: Three cryogenically cooled IR telescopes optically configured as a Jennison interferometer; optical or laser heterodyne detection.

REFERENCES: Concepts for an Infrared Interferometer in Space, NASA, March 1980.

CONTACTS: J. P. Murphy, ARC, (415) 965-6525

ASTROPHYSICS
MISSION TECHNOLOGY REQUIREMENTS

MISSION: INFRARED INTERFEROMETER A-18

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Physical Character			
Overall dimension(m)	100 x 15 x 9	3	
Total Mass (kg)	22,500	3	
Mass breakdown (kg)	ND	3	
Deployed/articulated items, size (m)			
Solar Arrays (2)	40	3	
Interferometer boom	100	3	
Telescopes (2)	9	3	Two telescopes translated along boom for variable baseline.
Cryogen storage capacity (1)	10^4	3	One tank per telescope.
Life			
Flight duration	5	3	Two Shuttle flights needed to deploy the facility; annual revisit for cryogen resupply.
Number of spacecraft	1	3	
Orbit			
Periapse/apoapse altitudes (km)	400-700	3	
Inclination (deg)	28-57	3	

ASTROPHYSICS
MISSION TECHNOLOGY REQUIREMENTS

MISSION: INFRARED INTERFEROMETER A-18

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Data			All parameters depend on choices made for detection method and for spacecraft vs. ground-based computers for image reconstruction.
Data volume (bits/day)	10^{10}-10^{12}	3,SOA	
Storage			
Capacity (bits)	10^{10}-10^{11}	3,SOA	
I/O rates (kbps)	ND	3	
Spacecraft processors/ computers			
I/O rates (kbps)	ND	3	
Memory size (bits)	ND	3	
Ground Processors/ computers			
Memory size (bits)	ND	3	
Communications			
Minimum/maximum downlink rates (kbps)	10^2-10^5	3,SOA	High rate digital data via TDRSS; rate depends on choices made for detection method and data processing.
Guidance & Attitude Control			
View direction	full sky	3	Three-axis stabilized by sensors, actuators on Science and Space Applications Platform. Pointing requirements depend on choice made for detection method; optical detection needs more stability. Fine pointing, alignment are actively controlled.
Position accuracy (km)	NA	3	
Pointing accuracy (mrad)	ND	3	
Stability (mrad)	ND	3	

ASTROPHYSICS
MISSION TECHNOLOGY REQUIREMENTS

MISSION: INFRARED INTERFEROMETER A-18

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Power			
Average power consumed (We)	25,000	3	Photovoltaic power source is part of Science and Space Applications Platform.
Peak power consumed (We)	59,000	3	
Power breakdown (We)	ND	3	
Energy Storage			
Storage capacity (J)	ND	3	NiCd batteries.
Discharge rate (We)	ND	3	
Discharge/recharge times (min)	30/60	3	
Thermal Control			
Component temperature (K)			
IR telescope	10-20	3,SOA	Liquid He stored in an external tank at each telescope; used to cool telescope and instruments. Detectors cooled by superfluid He.
IR sensors	2	3,SOA	
Component load (Wt)			
IR telescope	<10	3	
IR sensors	< 0.1	3	

ASTROPHYSICS
MISSION TECHNOLOGY REQUIREMENTS

MISSION: INFRARED INTERFEROMETER A-18

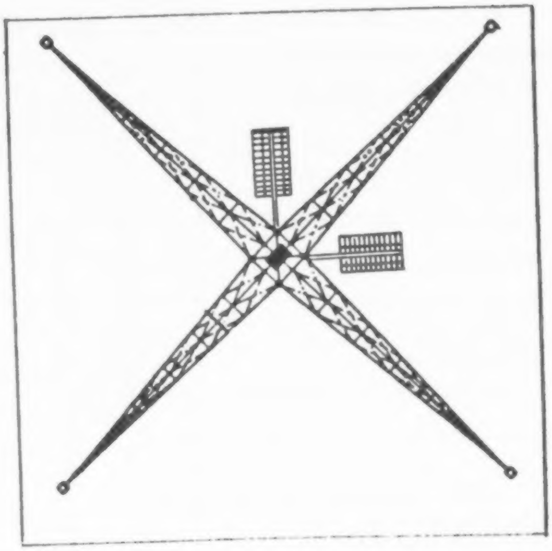
Mission Parameters (units)	Value	Confidence Level, Technology State	Comments
Chemical propulsion			
Total ΔV required (m/sec)	ND	3	May be needed for drag makeup; Shuttle or on-board system could be used.
Thrust level(N)			
Isp(sec)			
Propellant mass(kg)			
Inert mass(kg)			

ASTROPHYSICS
SENSOR/EXPERIMENT PARAMETERS

MISSION: INFRARED INTERFEROMETER A-18

Sensor or Experiment Name	Physical Property Measured/Property Range & Accuracy Resolution	Associated Ranges and/or Resolutions	Purpose, Component Properties, Other Comments
Jennison Triple Interferometer	Spatial distribution of infrared emission from celestial sources deduced from complex degree of coherence in incident wavefront	Spectral range of 5μm to 1 mm covered by several interferometric detectors (3,EV); high spectral resolution. Angular resolution of about 0.02 arc sec at 10μm (3,EV).	Study the morphology of galactic and extragalactic infrared sources. Candidate detection methods are direct combination of the optical beams and correlation of intermediate frequency signals formed by mixing signals from the three telescopes with a common local oscillator or laser source (heterodyne technique); former has greater sensitivity, and wider spectral range, but is more sensitive to mechanical instabilities (3,EV). Each telescope has a 1 m aperture (similar to SIRTF) and the position of two can be varied along the 100 m baseline (3,SOA).

MISSION: GRAVITY WAVE INTERFEROMETER A-19



atus:	Opportunity
fetime:	1-5 years
unch and Transfer hicles:	Shuttle
perational Location:	Earth orbit (altitude and inclination are not determined)
otal Mass at perational Location:	16,000 kg
verage Operational ower:	Not Determined

BJECTIVE: The Gravity Wave Interferometer searches for gravitational radiation from strophysical sources such as binaries, pulsars and black holes. The characteristics o be determined are the amplitude, the frequency bandwidth, polarization and, for ransient events, time history of amplitude and phase.

DESCRIPTION: A Shuttle based beam manufacturing machine is used to fabricate the arge antenna structure. The antenna has arm dimensions of about 1 km and has a 000 kg test mass at each tip. Inside the antenna is a Michelson interferometer hich is used to measure the strain $(\Delta\ell/\ell)$ caused by the interaction of gravity waves ith the antenna. An alternative is to measure with great accuracy the range between two "drag free" spacecraft. It is desirable to have coordinated observations with ther observatories, e.g., Space Telescope and Advanced X-ray Astrophysics Facility. Concept needs to be verified with a Phase A study.

CRITICAL TECHNOLOGY NEEDS: Large structures, mission design for low background noise, sensitive system for sensing mass positions.

INSTRUMENT OR EXPERIMENT COMPLEMENT: Gravity wave interferometer.

REFERENCES: Astrophysics Project Concept Summary: Gravity Wave Interferometer, NASA Headquarters, (Astrophysics Division), March 1978.

CONTACTS: M. Nein, GSFC, (205) 453-3430

ASTROPHYSICS
MISSION TECHNOLOGY REQUIREMENTS

MISSION: GRAVITY WAVE INTERFEROMETER A-19

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Physical Character			
Overall dimension(m)	1,000	3,EV	
Total Mass (kg)	16,000	3	
Mass breakdown (kg)			
Test masses (4)	4,000	3	
Structure	9,000	3	
Instruments, systems	1,000	3	
Deployed/articulated items, size (m)			
Large antenna arms (4)	500	3,EV	Fabricated in space using Shuttle based machine.
Test masses	0.5	3	Position controlled by servo system.
Life			
Flight duration (yrs.)	1-5	3	May require Shuttle revisits for resupply, refurbishment, orbit adjustments, etc.
Number of spacecraft	1	3	
Orbit			
Periapse/apoapse altitudes (km)	ND	3	Selected to reduce background noise due to gravity gradients.
Inclination (deg)	ND	3	

ASTROPHYSICS
MISSION TECHNOLOGY REQUIREMENTS

MISSION: GRAVITY WAVE INTERFEROMETER A-19

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Data			
Data volume (bits/day)	ND	3,SOA	
Storage			
Capacity (bits)	ND	3,SOA	
I/O rates (kbps)	ND	3	
Spacecraft processors/ computers			
I/O rates (kbps)	ND	3,EV	Signal processing needed to separate gravity wave signals from several sources from each other and from background noise.
Memory size (bits)	ND	3	
Ground Processors/ computers			
Memory size (bits)	ND	3,SOA	
Communications			
Minimum/maximum downlink rates (kbps)	ND	3,SOA	Use TDRSS link.
Guidance & Attitude Control			
View direction	full sky	3	Concept assumes three-axis stabilization using sun sensor, star trackers and gyros to control reaction wheels and thrusters. System must not interfere with interferometric measurements.
Position accuracy (km)	NA	3	
Pointing accuracy (mrad)	ND	3,SOA	
Stability (mrad)	ND	3,SOA	

ASTROPHYSICS
MISSION TECHNOLOGY REQUIREMENTS

MISSION: GRAVITY WAVE INTERFEROMETER A-19

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Power			
Average power consumed (We)	ND	3,SOA	Solar cells.
Peak power consumed (We)	ND	3	
Power breakdown (We)	ND	3	
Energy Storage			
Storage capacity (J)	ND	3	Batteries.
Discharge rate (We)	ND	3	
Discharge/recharge times (min)	ND	3	
Thermal Control			
Component temperature (K)	ND	3	Thermal gradients in the interferometer arms are a noise source.
Component load (Wt)	ND	3	

ASTROPHYSICS
MISSION TECHNOLOGY REQUIREMENTS

MISSION: GRAVITY WAVE INTERFEROMETER A-19

Mission Parameters (units)	Value	Confidence Level, Technology State	Comments
Chemical propulsion			
Total ΔV required (m/sec)	ND	3	Requirements depend on selected orbit.
Thrust level(N)			
Isp(sec)			
Propellant mass(kg)			
Inert mass(kg)			

ASTROPHYSICS
SENSOR/EXPERIMENT PARAMETERS

MISSION: GRAVITY WAVE INTERFEROMETER A-19

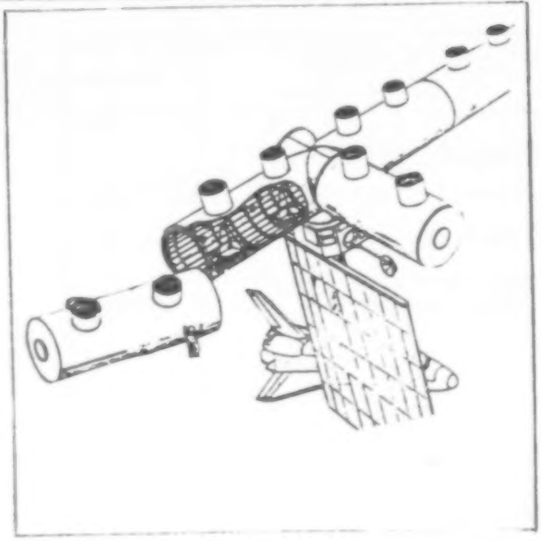
Sensor or Experiment Name	Physical Property Measured/Property Range & Accuracy Resolution	Associated Ranges and/or Resolutions	Purpose, Component Properties, Other Comments
Gravity Wave Interferometer	Strain ($\Delta \ell / \ell$) in gravity wave antenna; measure amplitude, (including time history), frequency bandwidth, polarization, and phase.	Frequency response should extend from about 10^{-4} Hz to about 10^{4}Hz (3,EV) Amplitude sensitivity of 10^{-21} (3,EV)	Detect gravity waves from astrophysical sources. Large masses (about 1000 kg) are located at tips of 1 km antenna. (3,EV) Strain detected by Michelson interferometer, using laser source and multipass interferometer arms with spherical mirrors (3,EV).

ASTROPHYSICS

MISSION: COHERENT OPTICAL SYSTEM OF MODULAR IMAGING COLLECTORS (COSMIC)

A-20

Status:	Opportunity
Lifetime:	10 years
Launch and Transfer Vehicles:	Shuttle, HLV/OTV
Operational Location:	Initially 500 km orbit at 28.5 deg; eventually geosynchronous
Total Mass at Operational Location:	Approximately 67,000 kg
Average Operational Power:	Approximately 25 kw



OBJECTIVE: The overall objective of the Coherent Optical System of Modular Imaging Collectors (COSMIC) is to increase the capabilities of UV/Optical/IR astronomy by several orders of magnitude more than Space Telescope. Typical science investigations are calibration of the distance scale beyond Virgo out to the Coma cluster, high resolution studies of quasars, search for planetary systems.

DESCRIPTION: Cosmic could be developed by NASA in the 1990's as a long-lived international observatory analogous to Space Telescope. A large coherent array of optical collectors is deployed in orbit by assembly of modules carried into orbit inside the Shuttle Orbiter bay. Initially only one module consisting of a 10 m baseline array is sufficient to prove the concept and at the same time significantly increase the angular resolution capability over Space Telescope. Several array geometries are under consideration which minimize the number of elements. An evolutionary development starting with a two-four element interferometer and evolving to a two dimensional array is proposed. The ultimate limit of such an approach depends upon the ability to manage the buildup of tolerances. The 100 Meter Thinned Aperture Telescope is an alternate method for providing significant advances for optical astronomy.

CRITICAL TECHNOLOGY NEEDS: Faster processes for fabrication and polishing of large mirrors, joining large modules to optical tolerances, adaptive control of flexible structures to optical tolerances, pointing stability.

INSTRUMENT OR EXPERIMENT COMPLEMENT: Options are Michelson interferometer, laser heterodyne interferometry and intensity interferometry.

REFERENCES: Astrophysics Project Summary: Coherent Optical System of Modular Imaging Collectors (COSMIC), NASA, March 1980.

CONTACTS: M. Nein, MSFC, (205) 453-3430

ASTROPHYSICS
MISSION TECHNOLOGY REQUIREMENTS

MISSION: COSMIC A-20

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Physical Character			
Overall dimension(m)	12x4(dia)	3	Size of basic unit; final configuration made up of many interconnected units to form two dimensional, non-redundant array.
Total Mass (kg)	67,000	3	
Mass breakdown (kg)			
Instruments	2,300	3	
Deployed/articulated items, size (m)			
Solar array	ND	3	
Active "tuners"	ND	3	Used to maintain identical path lengths for each interferometer element.
Folding mirrors	ND	3	Used to center images for each element.
Life			
Flight duration	10	3	Need on-orbit servicing.
Number of spacecraft	1	3	
Orbit			
Periapse/apoapse altitudes (km)	500	3	Initial orbit for construction, proof of concept. Eventual orbit would be geosynchronous.
Inclination (deg)	28.5	3	

ASTROPHYSICS
MISSION TECHNOLOGY REQUIREMENTS

MISSION: COSMIC A-20

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Data			
Data volume (bits/day)	10^{10}-10^{12}	3,SOA	
Storage			
Capacity (bits)	10^{10}-10^{11}	3,SOA	Tape recorders or equivalent.
I/O rates (kbps)	ND	3	
Spacecraft processors/ computers			
I/O rates (kbps)	ND	3	Monitor/correct to optical tolerances; control systems and instruments.
Memory size (bits)	ND	3	
Ground Processors/ computers			
Memory size (bits)	ND	3	Plan observing program; distribute data to investigators.
Communications			
Minimum/maximum downlink rates (kbps)	10^2-10^5	3,SOA	High rate digital data, real time and/or recorded; dedicated satellite relay link from low orbit; direct from geosynchronous orbit.
Guidance & Attitude Control			
View direction	full sky	3	Three axis stabilization; implementation is not determined.
Position accuracy (km)	NA	3	
Pointing accuracy (mrad)	ND	3	
Stability (mrad)	2×10^{-6}	3,EV	

ASTROPHYSICS
MISSION TECHNOLOGY REQUIREMENTS

MISSION: COSMIC A-20

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Power			
Average power consumed (We)	25,000	3	Photovoltaic
Peak power consumed (We)	ND	3	
Power breakdown (We)	ND	3	
Energy Storage			
Storage capacity (J)	ND	3	
Discharge rate (We)	ND	3	
Discharge/recharge times (min)	ND	3	
Thermal Control			
Component temperature (K)	ND	3	
Component load (Wt)	ND	3	

ASTROPHYSICS
MISSION TECHNOLOGY REQUIREMENTS

MISSION: COSMIC A-20

Mission Parameters (units)	Value	Confidence Level, Technology State	Comments
Chemical propulsion			
Total ΔV required (m/sec)	ND	3	Construction and initial operations are in low Earth orbit. Propulsion system needed for drag makeup and for transfer to eventual orbit at geosynchronous altitude.
Thrust level(N)			
Isp(sec)			
Propellant mass(kg)			
Inert mass(kg)			

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ASTROPHYSICS
SENSOR/EXPERIMENT PARAMETERS

MISSION: COSMIC A-20

Sensor or Experiment Name	Physical Property Measured/Property Range & Accuracy Resolution	Associated Ranges and/or Resolutions	Purpose, Component Properties, Other Comments
Michelson Interferometer	Complex degree of coherence in incident wavefront		Intensity distribution deduced from coherence data. Broad bandwidth is possible; short coherence length. Requires pathlength equality within several wavelengths for good quality fringes when beams are combined (3,EV).
Laser Heterodyne Interferometry	Same		At each element a heterodyne receiver mixes the signal with a local oscillator (laser). Resulting RF signals from each element are combined (3,EV). This method has a narrow bandwidth and, thus, reduced sensitivity.
Intensity Interferometry	Square of the modulus of the degree of coherence		At each element intensity fluctuations are detected and, then, combined electronically (3,SOA). Has reduced sentitivity.

ASTROPHYSICS

MISSION: LARGE OPTICAL/UV TELESCOPE A-21

Status: Opportunity

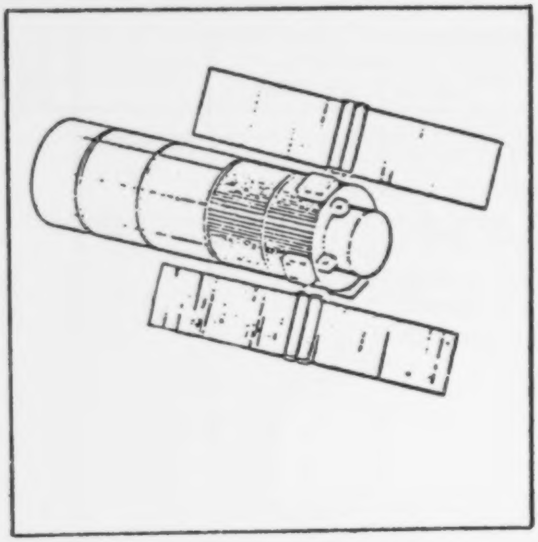
Lifetime: 10 years

Launch and Transfer Vehicles: Shuttle

Operational Location: 450 km at 28.5 deg.

Total Mass at Operational Location: 22,800 kg.

Average Operational Power: 6,000 w



OBJECTIVE: The Large Optical/UV Telescope, Diffraction Limited, is to have a tenfold increase in sensitivity over the Space Telescope (ST) presently under development. Thus, it can extend the distance scales for astronomical observations. This is especially important for such areas as detection of extrasolar planetary systems, extragalatic astronomy and observational cosmology.

DESCRIPTION: The telescope concept which is presently considered feasible consists of a Ritchey-Chretien all reflective system with an 8 m aperture. The telescope components are carried into orbit in the Shuttle orbiter cargo bay and a modified external tank, (primary structure and mirror cell, etc.). On-orbit deployment and assembly are required. The mission profile projects permanent operation in orbit with periodic maintenance and instrument changeouts. Study activity is currently limited to assessment of overall feasibility and concept options.

CRITICAL TECHNOLOGY NEEDS: Mirror technology (fabrication of lightweight, segmented mirror, active figure control, on-orbit cleaning and recoating), high resolution detectors (electronic and film), point stability; orbital assembly, fabrication of telescope.

INSTRUMENT OR EXPERIMENT COMPLEMENT: A variety of instruments can be accommodated in a modular fashion in either an axial or radial configuration. Typical instruments are a wide field camera, spectrometers and photometers.

REFERENCES:

CONTACTS: M. Nein, MSFC, (205)453-3430

ASTROPHYSICS

MISSION TECHNOLOGY REQUIREMENTS

MISSION: LARGE OPTICAL/UV TELESCOPE A-21

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Physical Character			
Overall dimension(m)	28.5x8.4 (dia)	3, REV	Observatory is spacecraft constructed in space using pieces brought up in the Shuttle cargo bay and external tank.
Total Mass (kg)	22,800	3	
Mass breakdown (kg)			
Telescope	21,200		
Instruments	1,600		
Deployed/articulated items, size (m)			
Telescope Barrel	28.25x8.4 (dia)	3, REV	
Mirror	8 (dia)	3, REV	The primary mirror is a segmented mirror with each section being actively aligned. Figure control is accomplished by piezo-electrically activated control rods with figure errors sensed by laser interferometry.
Solar Arrays(2)	4x16	3, SOA	
Life			
Flight duration (years)	10	3, SOA	Shuttle revisits at 6-month intervals for servicing, instrument changeouts, etc.
Number of spacecraft	1		
Orbit			
Periapse/apoapse altitudes (km)	450	3, SOA	
Inclination (deg)	28.5		

ASTROPHYSICS

MISSION TECHNOLOGY REQUIREMENTS

MISSION: LARGE OPTICAL/UV TELESCOPE A-21

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Data			
Data volume (bits/day)	ND	3, SOA	Data system requirements probably similar to Space Telescope.
Storage			
Capacity (bits)	ND	3, SOA/EV	Tape recorders and high resolution film.
I/O rates (kbps)	ND	3, SOA/EV	
Spacecraft processors/ computers			
I/O rates (kbps)	ND	3, SOA	
Memory size (bits)	ND	3, SOA	
Ground Processors/ computers			
Memory size (bits)	ND	3, SOA	
Communications			
Minimum/maximum downlink rates (kbps)	ND	3, SOA	Use TDRSS; rates and type of service may be similar to Space Telescope.
Guidance & Attitude Control			
View direction	All Sky	3, SOA	Spacecraft is three-axis stabilized and inertially pointed to desired astronomical object. Image motion compensation required for final image stability. Startrackers and gyros provide attitude reference; control moment gyros (like ATM) are used as primary actuators.
Position accuracy (km)	ND	3	
Pointing accuracy (mrad)	.005	3, SOA	
Stability (mrad)	10^{-5}	3, EV	

ASTROPHYSICS

MISSION TECHNOLOGY REQUIREMENTS

MISSION: LARGE OPTICAL/UV TELESCOPE A-21

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Power			
Average power consumed (We)	6,000	3, SOA	Photovoltaic
Peak power consumed (We)	12,000		
Power breakdown (We)	ND		
Energy Storage			
Storage capacity (J)	ND		
Discharge rate (We)	ND	3, SOA	Batteries, NiCd or equivalent.
Discharge/recharge times (min)	ND		
Thermal Control			
Component temperature (K)			
Mirrors & Telescope Structure	295	3, SOA	Thermal stability of these components is needed to provide a stable focus for the telescope. Passive thermal control methods are used including paints, coatings, insulation and thermostatically controlled heaters.
Component load (Wt)			
Mirrors & Telescope Structure	ND		

ASTROPHYSICS

MISSION TECHNOLOGY REQUIREMENTS

MISSION: LARGE OPTICAL/UV TELESCOPE A-21

Mission Parameters (units)	Value	Confidence Level, Technology State	Comments
Chemical propulsion			
Total ΔV required (m/sec)	NA		Orbit adjustments performed during Shuttle revisits.
Thrust level(N)			
Isp(sec)			
Propellant mass(kg)			
Inert mass(kg)			

SENSOR/EXPERIMENT PARAMETERS

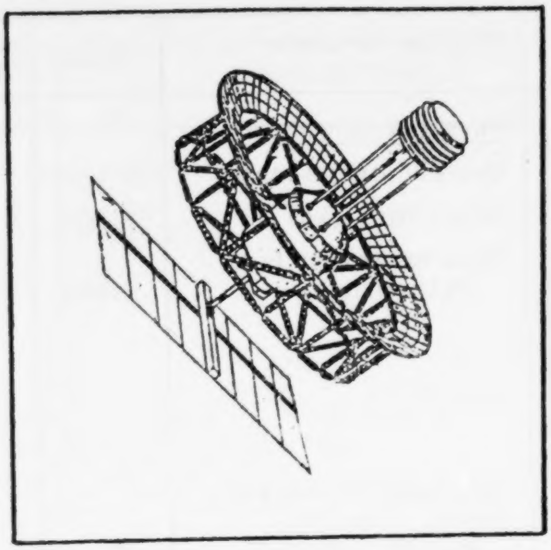
MISSION: LARGE OPTICAL/UV TELESCOPE

A-21

Sensor or Experiment Name	Physical Property Measured/Property Range & Accuracy Resolution	Associated Ranges and/or Resolutions	Purpose, Component Properties, Other Comments
Primary Mirror	NA	NA	An 8 m diameter segmented f/2.2 mirror. Central circular segment is surrounded by eight identical pie-shaped mirrors. All are polished for diffraction limited performance (3,EV) Segments have area similar to ST primary, but weigh 80% less, thus requiring new materials, production methods and active figure controls. (3,REV). All segments are assembled into mirror cell which is carried into orbit with a Shuttle external. tank (3,EV).
Wide Field Camera (typical instrument)	Spatial distribution of brightness of astronomical objects for visual magnitudes between 10 and 30 with 1% resolution	Spectral range of 115 to 1100 μm with resolution defined by filters (3, SOA); Angular resolution of about 0.03 arc sec. (3,EV)	Used to map galaxies, search for planets, etc. High photometric and geometric accuracy. Film and/or electronic sensors with spatial resolution of <1μm and about 10μm respectively (3,EV).

MISSION: 100 METER THINNED APERTURE TELESCOPE A-22

Status:	Opportunity
Lifetime:	10 years
Launch and Transfer Vehicles:	Shuttle, HLV, OTV, IUS
Operational Location:	Initially 500 km orbit at 28.5 deg; eventually geosynchronous
Total Mass at Operational Location:	Approximately 85,000 kg
Average Operational Power:	Approximately 25 kw



OBJECTIVE: The 100 Meter Thinned Aperture Telescope (TAT) has as its basic objectives a 30 fold increase in image resolution and a 1000 fold increase in astrometric precision over that afforded by the Space Telescope. Typical science investigations are calibration of the distance scale beyond Virgo and out to the Coma cluster of galaxies, high resolution studies of quasars, and a search for planetary systems.

DESCRIPTION: The TAT could be developed by NASA in the 1990's and managed as a long-lived international observatory analogous to Space Telescope. The large aperture telescope is deployed in low earth orbit using advanced assembly techniques. Several Shuttle flights provide for assembly of the initial structure including fabrication of structural components, attachment of the equipment and instrument sections and the solar arrays. Addition of the primary and secondary mirror segments proceeds in an incremental fashion to provide an early initial capability to obtain high resolution observations of brighter sources. Eventual filling in of sections of the annular mirrors will provide the full capability for faint object detection.

CRITICAL TECHNOLOGY NEEDS: Faster processes for fabrication and polishing of large, lightweight mirrors, orbital manufacture of structural elements and assembly of optical system, adaptive control of flexible structures to optical tolerances, pointing stability, high resolution detectors.

INSTRUMENT OF EXPERIMENT COMPLEMENT: A versatile observatory with multiple replaceable instruments such as imagery, photometry, spectroscopy, and astrometry.

REFERENCES: Astrophysics Project Summary: 100 Meter Thinned Aperture Telescope, NASA, March 1980.

CONTACTS: M. Nein, MSFC, (205) 453-3430

ASTROPHYSICS
MISSION TECHNOLOGY REQUIREMENTS

MISSION: 100 METER THINNED APERTURE TELESCOPE A-22

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Physical Character			
Overall dimension(m)	100 (dia)	3	TAT Structure is manufactured in space, optical system is assembled in space.
Total Mass (kg)	85,000	3	
Mass breakdown (kg)			
Instruments	2,000	3	
Deployed/articulated items, size (m)			
Secondary mirrors	ND	3	Articulated for image motion compensation and background chopping.
Primary mirrors	4 x 4	3	Active control of figure.
Solar arrays	ND	3	
Life			
Flight duration	10	3	Manned visits for on-orbit maintenance.
Number of spacecraft	1	3	
Orbit			
Periapse/apoapse altitudes (km)	500	3	Construction and initial operational orbit; eventual orbit is geosynchronous.
Inclination (deg)	28.5	3	

ASTROPHYSICS
MISSION TECHNOLOGY REQUIREMENTS

MISSION: 100 METER THINNED APERTURE TELESCOPE A-22

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Power			
Average power consumed (We)	25,000	3	Photovoltaic.
Peak power consumed (We)	ND	3	
Power breakdown (We)	ND	3	
Energy Storage			
Storage capacity (J)	ND	3	
Discharge rate (We)	ND	3	
Discharge/recharge times (min)	ND	3	
Thermal Control			
Component temperature (K)	ND	3	
Component load (Wt)	ND	3	

ASTROPHYSICS
MISSION TECHNOLOGY REQUIREMENTS

MISSION: 100 METER THINNED APERTURE TELESCOPE A-22

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Data			
Data volume (bits/day)	$10^{10} - 10^{12}$	3,SOA	
Storage			
Capacity (bits)	$10^{10} - 10^{11}$	3,SOA	Tape recorders or equivalent.
I/O rates (kbps)	ND	3	
Spacecraft processors/ computers			Monitor/correct to optical tolerances; control systems and instruments.
I/O rates (kbps)	ND	3	
Memory size (bits)	ND	3	
Ground Processors/ computers			
Memory size (bits)	ND	3	Plan observing program; distribute data to investigators.
Communications			
Minimum/maximum downlink rates (kbps)	$10^2 - 10^5$	3,SOA	High rate digital data, real time and/or recorded; dedicated satellite relay link from low orbit; direct from geosynchronous orbit.
Guidance & Attitude Control			Three axis stabilization; implementation is not determined.
View direction	full sky	3	
Position accuracy (km)	NA		
Pointing accuracy (mrad)	ND	3	
Stability (mrad)	2×10^{-6}	3,EV	

ASTROPHYSICS
MISSION TECHNOLOGY REQUIREMENTS

MISSION: 100 METER THINNED APERTURE TELESCOPE A-22

Mission Parameters (units)	Value	Confidence Level, Technology State	Comments
Chemical propulsion			
Total ΔV required (m/sec)	ND	3	Construction and initial operations are in low Earth orbit. Propulsion system needed for drag makeup and for transfer to eventual orbit at geosynchronous altitude.
Thrust level(N)			
Isp(sec)			
Propellant mass(kg)			
Inert mass(kg)			

ASTROPHYSICS
SENSOR/EXPERIMENT PARAMETERS

MISSION: 100 METER THINNED APERTURE TELESCOPE A-22

Sensor or Experiment Name	Physical Property Measured/Property Range & Accuracy Resolution	Associated Ranges and/or Resolutions	Purpose, Component Properties, Other Comments
Not determined--could be similar to Space Telescope		Higher angular resolution than ST to about 10^{-3} arc sec for imagery and 10^{-6} arc sec for astrometry (3,EV)	Need electronic sensors with larger formats ($10^4 \times 10^4$) and smaller pixel sizes (3,EV).

SOLAR TERRESTRIAL

The Solar Terrestrial program objective is to understand the important physical processes in the sun, in the solar neighborhood, in the earth-space region, and in the upper atmosphere. Current efforts include remote observations of the sun and the various manifestations of the solar cycle, and remote and in situ measurements in the near-earth region. Future emphasis will be on more detailed investigations of cause and effect, using measurements close to the sun and from simultaneous measurements in widely separated locations in the solar system.

SOLAR TERRESTRIAL

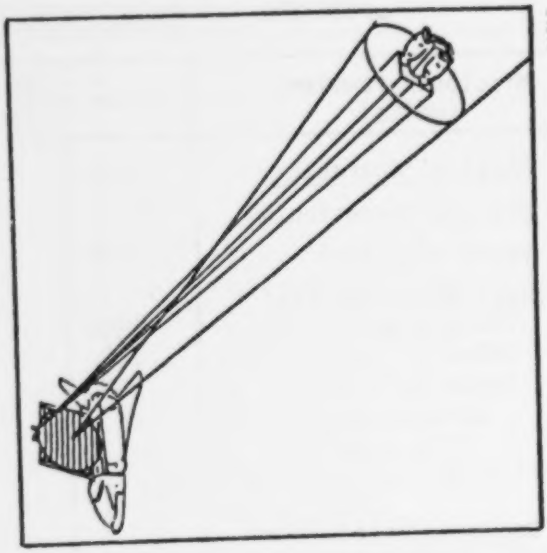
No.

S-14 Pinhole Satellite consists of a large random array pinhole mask and a free-flyer to detect X-ray images.

S-15 Close Solar Orbiter will investigate and determine the global characteristics of the sun.

MISSION: PINHOLE SATELLITE S-14

Status:	Opportunity
Lifetime:	7-14 days
Launch and Transfer Vehicles:	Shuttle/Spacelab
Operational Location:	370 km orbit at 97 deg. inclination
Total Mass at Operational Location:	About 10,000kg
Average Operational Power:	Not determined



OBJECTIVE: One of the outstanding questions of solar atmospheric physics concerns the transport of energy and mass in the corona. To understand this transport, one needs, among other data, high spatial-resolution information, both at X-ray wavelengths and in the UV and Optical domains. The availability of such X-ray data, which can be secured with a pinhole satellite system, will help clarify crucial questions concerning the energy budget in the solar atmosphere.

DESCRIPTION: For this NASA Solar Terrestrial Physics mission a large random array pinhole mask of lead or tungsten is deployed from the orbiter cargo bay. An X-ray detector mounted on a maneuverable subsatellite is launched from the orbiter into a co-planar orbit 1 km from the mask and aligned to detect solar X-ray images formed by the pinholes of the mask. The pinhole mask is stabilized by the orbiter attitude control system. Laser alignment beams emanating from the mask-mounted aspect sensing system are reflected from the detector spacecraft to provide a position history of the detector with respect to the occulting mask. Post-flight deconvolution of the images in conjunction with the very accurate mask/detector position information will result in resolution of X-ray images (10 to 100 keV) of better than 1 arc sec. (0.2 - 1 arc sec). Other concepts for separating the pinhole array and the detectors have been defined.

CRITICAL TECHNOLOGY NEEDS: Large X-ray detector arrays, high accuracy pinhole mask manufacture, high precision alignment systems, image reconstruction method.

INSTRUMENT OR EXPERIMENT COMPLEMENT: X-ray imaging detector at focal plane, white light coronograph and UV coronograph/spectrometer.

REFERENCES: "Solar Terrestrial Mission Concept: Pinhole X-ray Satellite", NASA Headquarters, July 1979.

CONTACTS: J. Dabbs, MSFC (205)453-3430

SOLAR TERRESTRIAL

MISSION TECHNOLOGY REQUIREMENTS

MISSION: PINHOLE SATELLITE S-14

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Physical Character			
Overall dimension(m)	37x24x 25	3	Shuttle dimensions with deployed pinhole mask.
Total Mass (kg)	9100	3	
Mass breakdown (kg)			
Pinhole mask	2900		
Detector Subsatellite	2800		
Spacelab Systems	3400		Includes about 1000 kg for solar physics instruments on Spacelab pallet.
Deployed/articulated items, size (m)			
Pinhole Mask	20 (dia)	3, EV	
Detector Subsatellite	ND	3, EV	Depends on field-of-view desired.
Life			
Flight duration (days)	7	3	
Number of spacecraft	1	3	
Orbit			
Periapse/apoapse altitudes (km)	370	3	Nominal Shuttle orbit plane is always perpendicular to the Sun-Earth line. Subsatellite orbit is coplaner with 1 km offset.
Inclination (deg)	97	3	

SOLAR TERRESTRIAL
MISSION TECHNOLOGY REQUIREMENTS

MISSION: PINHOLE SATELLITE S-14

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Data			
Data volume (bits/day)	ND	3	
Storage			
Capacity (bits)	ND	3	Use Spacelab tape recorder, if needed.
I/O rates (kbps)	ND	3	
Spacecraft processors/ computers			
I/O rates (kbps)	ND	3	Data handling and attitude control. Functions split between Spacelab and subsatellite
Memory size (bits)			
Ground Processors/ computers			
Memory size (bits)	ND	3	Used for image reconstruction.
Communications			
Minimum/maximum downlink rates (kbps)	ND	3	S-band link for digital data between subsatellite and Shuttle; K_u- or S-band link from Shuttle to TDRSS.
Guidance & Attitude Control			
View direction	Sun	3	Subsatellite and pinhole mask must maintain an accurate position and relative angular alignment during data acquisition. Relative position/angles determined by optical system on Shuttle which uses retro-reflector prisms on subsatellite. Mask pointed at Sun by Shuttle using Sun/Stellar trackers.
Position accuracy (km)	10^{-4}	3, EV	
Pointing accuracy (mrad)	0.002	3, EV	
Stability (mrad)	0.002	3, EV	

SOLAR TERRESTRIAL
MISSION TECHNOLOGY REQUIREMENTS

MISSION: PINHOLE SATELLITE S-14

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Power			
Average power consumed (We)	ND	3	Shuttle/Spacelab has adequate power for pinhole mask and solar physics experiments. Subsatellite requires solar independent power (fuel cells or RTG).
Peak power consumed (We)	ND	3	
Power breakdown (We)	ND	3	
Energy Storage			
Storage capacity (J)	ND	3	
Discharge rate (We)	ND	3	Probably not needed.
Discharge/recharge times (min)	ND	3	
Thermal Control			
Component temperature (K)	ND	3	Subsatellite will be occulted at all times; must be well insulated.
Component load (Wt)	ND	3	

SOLAR TERRESTRIAL

MISSION TECHNOLOGY REQUIREMENTS

MISSION: PINHOLE SATELLITE S-14

Mission Parameters (units)	Value	Confidence Level, Technology State	Comments
Chemical propulsion			
Total ΔV required (m/sec)	750	3	Hydrazine propulsion system used to offset subsatellite orbit; requires about 7m/sec/orbit for seven days; thrust level is low, used almost continuously.
Thrust level(N)	ND	3	
Isp(sec)	240	3, SOA	
Propellant mass(kg)	600	3	
Inert mass(kg)	ND	3	

SOLAR TERRESTRIAL

SENSOR/EXPERIMENT PARAMETERS

MISSION: PINHOLE SATELLITE S-14

Sensor or Experiment Name	Physical Property Measured/Property Range & Accuracy Resolution	Associated Ranges and/or Resolutions	Purpose, Component Properties, Other Comments
Pinhole Mask/ Occulter			A large disk (20 m dia.) which >95% of X-rays in the energies <100 keV; 50% of the mask is transparent to X-rays through random 5mm dia holes (3,EV) produces image with 1 arc sec resolution at range of 1 km. Also used to occult solar disk for UV/visual coronographs.
X-ray Detector	Hard X-ray flux from solar disk	Energy range of 10 to 100 keV with extended coverage to ≈10 MeV. Time resolution <1 sec. Angular resolution of 1.0 arc sec. (3,SOA)	Obtains images of active solar regions with reconstruction of observations. Nominal detector is NaI(Tl) scintilation counters and consists of 4×10^4 or more elements, each 5 mm in size. (3,EV)
Coronograph/ Spectrometer	Line and continuum emission from solar corona	Spectral range of 0.1 to 1.0 μm; resolution of 0.1% or better. Angular resolution of 1.0 arc sec. (3,SOA)	Measures light from inner corona; relatively large telescope diameter (>20 cm) permitted and needed for angular resolution. Emission/absorption line profiles used to determine temperature, density and ionization equilibrium in coronal streamers.

SOLAR TERRESTRIAL

MISSION: CLOSE SOLAR ORBITER S-15

Status: Opportunity

Lifetime: Not determined

Launch and Transfer Vehicles: Shuttle plus upper stage

Operational Location: Heliocentric orbit

Total Mass at Operational Location: Not determined

Average Operational Power: Not determined

OBJECTIVE: Close Solar Orbiter will investigate and determine the global characteristics of the Sun to the extent possible from a science platform in a low perihelion, low period solar orbit. Return of a dynamical picture of the processes of the Sun and its environment is a major objective.

DESCRIPTION: The Close Solar Orbiter is a mission concept being considered by NASA's Solar Terrestrial Division. Mission development will be based on technology and science return from two preceding missions, International Solar Polar Mission (ISPM) and Solar Probe. Study activity with regard to the Close Solar Orbiter mission concept will begin in January 1980 and will generate a trajectory data base on which future mission concepts can rest. Trajectory modes considered will include solar sail and gravity-assist.

CRITICAL TECHNOLOGY NEEDS: Propulsion and communication systems operating over a wide range of thermal conditions, solar sail structures operating at close distances from the Sun.

INSTRUMENT OR EXPERIMENT COMPLEMENT: Not determined.

REFERENCES: None.

CONTACTS: R.A. Wallace, JPL, (213)354-6162

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LIFE SCIENCES

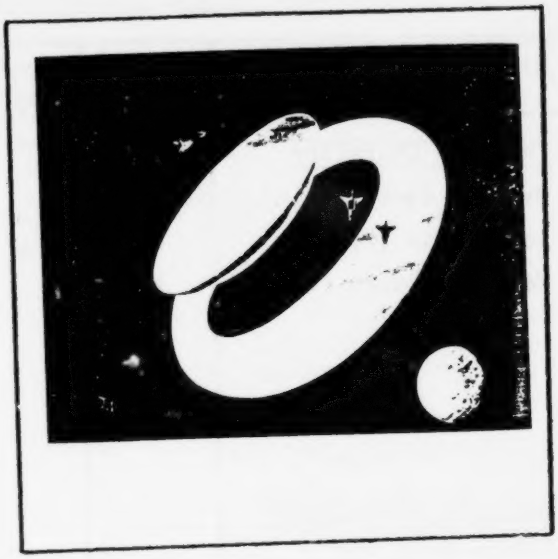
The objectives of the Life Sciences program are to utilize the space environment to advance knowledge in medicine and biology, to ensure human health, safety, well being, and effective performance in space flight, and to gain a better understanding of the origin and distribution of life in the universe. Past investigations have focused on evaluating possible hazards to crew health and on identifying factors that could impair crew performance. The early Shuttle-Spacelab flights will emphasize the investigation and understanding of physiological performance and changes which have been observed in humans who have flown in space, and on the identification and investigation of significant biological phenomena which may occur during and/or after exposure to the space environment. Related Shuttle-Spacelab experiments will exploit the zero-gravity aspects of the space environment to study the fundamental responses of humans and other organisms to gravity. These investigations will be performed in the pressurized cabin of the Space Shuttle Orbiter, or in a pressurized Spacelab module, or attached to an unpressurized Spacelab pallet. The Life Sciences also encompasses the research known as the Search for Extraterrestrial Life and Intelligence.

LIFE SCIENCES MISSIONS

NO.	
L-3	Search for Extraterrestrial Intelligence (SETI) has as its objective the detection of radio signals transmitted by intelligent beings.

MISSION: SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE L-3

Status:	Opportunity
Lifetime:	10 years
Launch and Transfer Vehicles:	Shuttle
Operational Location:	L3, other options
Total Mass at Operational Location:	Not determined
Average Operational Power:	Not determined



OBJECTIVE: The search for Extraterrestrial Intelligence (SETI) program has as its objective the detection of radio signals transmitted by intelligent beings. The search would attempt to find unintentional signals similar to the radar and TV signals from Earth as well as intentional messages from nearby stars. The SETI system would also be useful for general astrophysical investigations of radio sources.

DESCRIPTION: One concept for a system in space consists of a spherical primary reflector made of lightweight mesh, with three Gregorian subreflectors and feed assemblies that permit three different stars to be searched simultaneously. A disk-shaped shield placed between the antenna and the Earth protects against radio frequency interference (RFI); a series of relay satellites permits the IF signal to be beamed to Earth for processing and to transmit instructions from Earth for station-keeping and attitude control. A number of orbital locations are possible, including the L3 libration point of the Earth-Moon system, a point at lunar distance but on the opposite side of the Earth from the Moon. Among several desirable features of an orbiting antenna system are the complete sky coverage, the ability to track a given star continuously if a signal is detected, the reduced system temperature, and the potential structural simplicity and longevity made possible by the weightless and benign environment. Further studies are needed of the space-based SETI and of the alternatives which are based on the Earth or the far side of the Moon.

CRITICAL TECHNOLOGY NEEDS: Large structure for antenna; low noise, wide bandwidth receiver; relay link to Earth; maintenance of the SETI system.

INSTRUMENT OR EXPERIMENT COMPLEMENT: Multiple feeds with low noise, wide bandwidth receivers.

REFERENCES: The Search for Extraterrestrial Life, Morrison, P., et al eds. NASA SP-419, 1977

CONTACTS: M. Sander, SB-5, (202) 755-3726

LIFE SCIENCES

MISSION TECHNOLOGY REQUIREMENTS

MISSION: SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE L-3

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Physical Character			
Overall dimension(m)	600 (dia)	3	
Total Mass (kg)	ND		
Mass breakdown (kg)	ND		
Deployed/articulated items, size (m)			
Antenna	300 (dia)	3,EV	Lightweight mesh spherical reflector constructed in space.
RFI Shield	600 (dia)	3	Shields antenna from Earth and satellite interference.
Life			
Flight duration (yrs)	10	3	On-orbit maintenance may be needed.
Number of spacecraft	1	3	
Orbit			
Periapse/apoapse altitudes (km)	3.8×10^5	3	Orbit at L3 of Earth-Moon system is reasonable choice considering accessibility for data transmission and maintenance and RFI from the Earth. Alternatives are lunar far side and heliocentric orbits.
Inclination (deg)	low	3	

LIFE SCIENCES
MISSION TECHNOLOGY REQUIREMENTS

MISSION: SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE L-3

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Data			
Data volume (bits/day)	Up to 10^{16}	3,EV	
Storage			
Capacity (bits)	NA		
I/O rates (kbps)	NA		
Spacecraft processors/ computers			Used for system control, only.
I/O rates (kbps)	ND	3	
Memory size (bits)	ND	3	
Ground Processors/ computers			Signal processor with 10^6 to 10^9 channels needed to keep search time short.
Memory size (bits)	$>10^9$	3,EV	
Communications			Intermediate frequency (analog) signal transmitted via relay satellite to Earth; several channels needed.
Minimum/maximum downlink bandwidth (MHz)	300	3,SOA	
Guidance & Attitude Control			Antenna must be pointed at particular stars with accuracy and stability finer than its beamwidth of about 2 arc min. Implementation is not determined.
View direction	full sky	3	
Position accuracy (km)	ND	3	
Pointing accuracy (mrad)	0.5	3,EV	
Stability (mrad)	0.2	3,EV	

LIFE SCIENCES
MISSION TECHNOLOGY REQUIREMENTS
MISSION: SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE L-3

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Power			
Average power consumed (We)	ND	3	
Peak power consumed (We)	ND	3	
Power breakdown (We)	ND	3	
Energy Storage			
Storage capacity (J)	NA	3	
Discharge rate (We)			
Discharge/recharge times (min)			
Thermal Control			
Component temperature (K)	ND	3	Receiver is cryogenically cooled maser.
Component load (Wt)	ND	3	

LIFE SCIENCES

MISSION TECHNOLOGY REQUIREMENTS

MISSION: SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE L-3

Mission Parameters (units)	Value	Confidence Level, Technology State	Comments
Chemical propulsion			
Total ΔV required (m/sec)	ND	3	SETI system must be transferred from low Earth orbit to L3 or other operating orbit. Since construction probably is done in low Earth orbit, high thrust levels cannot be used in transfer.
Thrust level(N)			
Isp(sec)			
Propellant mass(kg)			
Inert mass(kg)			

LIFE SCIENCES

SENSOR/EXPERIMENT PARAMETERS

MISSION: SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE L-3

Sensor or Experiment Name	Physical Property Measured/Property Range & Accuracy Resolution	Associated Ranges and/or Resolutions	Purpose, Component Properties, Other Comments
Radio Receivers	Radio signals from extraterrestrial sources	Frequency range of 1400 to 1727 MHz, the "water hole" (3,EV), with frequency resolutions between 10^{-2} and 10^{3} Hz (3,EV)	Search for intentional signals transmitted by intelligent life in a nearby stellar system. Also sensitive to unintentional transmissions like TV and radar. Receivers located at focal plane of large radiotelescope (diameter of about 300m). Receiver noise temperature less than galactic background of about 4K (3,EV). Detected intermediate frequency transmitted to Earth for final processing.

RESOURCE OBSERVATION

The Resource Observation program objectives include forecasting of agricultural production, exploration for mineral and energy resources, management of land use and water resources, and assessment of geodynamic hazards. Current efforts are concentrated in utilizing medium- to low-resolution instruments in a few spectral regions. Future emphasis will be on high-resolution (temporal, spatial, and spectral) studies in truly multispectral fashion, including magnetic, microwave, IR, visible, and stereo data.

RESOURCE OBSERVATION MISSIONS

No far-term mission systems were identified by the program office for inclusion in the Model.

RESOURCE OBSERVATION INSTRUMENTS

No.	
RI-17	Nd:YAG Spaceborne Laser System

INSTRUMENT: Nd: YAG Spaceborne Laser System, Ground Retroreflector RI-17

STATUS: Opportunity

CARRIER: ND

PHYSICAL AND GENERAL PROPERTIES:

Physical Size (m):

Power Requirement (We): 300 W (peak)

Mass (kg): 115

Data Rate (kbps):

PRINCIPAL PURPOSE AND FEATURES:

Satellite-borne laser system used with ground-based reflector assembly for ranging and monitoring, frequently over long time periods, the relative positions of many geodetic reference points.

PRINCIPAL PHYSICAL PROPERTY MEASURED, RANGE, ACCURACY, AND RESOLUTION:

Range to ground-based reflector; 15-20 range measurements per detector. Ground position shifts of 1-5 cm detectable in 1 week.

ASSOCIATED RANGES AND/OR RESOLUTION:

0.05 mr beam divergence (2,EV); 200 ps pulse width, 10 pulses/sec (2,EV).

COMMENTS:

Data used for fault zone monitoring in support of earthquake prediction, plate tectonic motion and deformation, base-line determination in support of global survey activities, improvement in the knowledge of the earth's rotation and polar motion.

Recent decisions have terminated work on this concept because it appears to be decidedly less attractive than ground-based laser tectonic measurement.

SOURCE/CONTACT:

T. Fichetti, NASA HE, Code ERG-2, 755-3848

M. Fitzmaurice, GSFC

GLOBAL ENVIRONMENT

The Global Environment program objectives include monitoring and forecasting of global weather and local severe storms, assessment and forecasting of climate, monitoring and forecasting of ocean conditions, and assessment of air and water quality. The future emphasis will be on multi-instrument systems to measure a variety of phenomena simultaneously, and on geosynchronous observations.

GLOBAL ENVIRONMENT MISSION

No far-term mission systems were identified by the program office for inclusion in the Model.

GLOBAL ENVIRONMENT INSTRUMENTS

No.	
EI-68	Atmospheric Cloud Physics Laboratory

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INSTRUMENT: Atmospheric Cloud Physics Laboratory (ACPL) EI-68

STATUS: Opportunity

CARRIER:

PHYSICAL AND GENERAL PROPERTIES:

Physical Size (m): 2.65 m^3

Mass (kg): 549

Power Requirement (We): 1063 (340 dc and 723 ac)

Data Rate (kbps): 1

PRINCIPAL PURPOSE AND FEATURES:

To develop a unique multipurpose laboratory facility for conducting atmospheric cloud microphysics research which will increase the level of knowledge and thereby increase the ability to better predict the weather. Features one double and one single rack mounted equipment consisting of aerosol generator, experiment chamber, saturator, camera, particle counter, thermal conditioner, etc.

PRINCIPAL PHYSICAL PROPERTY MEASURED, RANGE, ACCURACY, AND RESOLUTION:

See attachments

ASSOCIATED RANGES AND/OR RESOLUTION:

COMMENTS:

Development contract cancelled.

SOURCE/CONTACT: J. Dodge, NASA HQ, EBT-8; R. Arnold, NASA HQ, EB-8; Experiment Requirements Document, 28 December 1977; IPRD on SL-3, Document No. JA-019, November 1978; C. Ellswirth, MSFC, 205/453-2102; Atmospheric Cloud Physics Laboratory, Project Plan, MSFC, 1 March 1976.

PRINCIPAL PHYSICAL PROPERTY MEASURED, RANGE, ACCURACY, AND RESOLUTION:

ACPL

EI-68

Sensor or Experiment Name	Physical Property Measured/Property Range & Accuracy Resolution	Associated Ranges and/or Resolutions	Purpose, Component Properties, Other Comments
Condensation Nucleation			Determine the nucleation efficiencies & early growth properties of soluble, insoluble, & hydrophobic nuclei. This class of experiments encompasses a large range of nuclei types, size, distributions, & relative humidities.
Ice Nucleation			Determine the relative importance of contact internal, & sublimation nucleation of ice. Absolute nucleation efficiencies will also be studied as a function of nuclei types & sizes.
Ice Multiplication			Determine the conditions under which ice fragments are generated during atmospheric precipitation processes & the extent to which they are generated.
Charge Separation (Electrification)			Determine quantitative values for charge transfer occurring during several important atmospheric processes.
Ice Crystal Growth Habit			Determine the temperature, pressure, & relative humidity conditions which dictate ice crystal geometry & growth rate under pure diffusion (nonconvection) conditions.

PRINCIPAL PHYSICAL PROPERTY MEASURED, RANGE, ACCURACY, AND RESOLUTION:

Sensor or Experiment Name	Physical Property Measured/Property Range & Accuracy Resolution	Associated Ranges and/or Resolutions	Purpose, Component Properties, Other Comments
Scavenging			Determine the relative & quantitative importance of thermal (thermophoresis), & Brownian forces in the collection of submicrometer aerosol particles by cloud droplets.
Riming and Aggregation			Determine interaction between a super-cooled water droplet & an ice surface during events associated with riming & graupel formation.
Droplet-Ice Cloud Interactions			Determine the modes & extent of the interactions of ice crystals & super-cooled water droplets, including the propragation of the ice phase through a super-cooled droplet cloud & the diffusion growth of ice crystals within a cloud of super-cooled droplets under varying conditions of temperature, pressure, & droplet/crystal concentration.
Homogeneous Nucleation (Ice)			Determine the homogeneous freezing distribution of droplets as a function of time, degree of super-cooling, & droplet diameter under conditions of no physical supports.

PRINCIPAL PHYSICAL PROPERTY MEASURED, RANGE, ACCURACY, AND RESOLUTION:

Sensor or Experiment Name	Physical Property Measured/Property Range & Accuracy Resolution	Associated Ranges and/or Resolutions	Purpose, Component Properties, Other Comments
Collision-Induced Freezing			Determine the conditions & frequency of droplet freezing due to collisions of super-cooled droplets ad a function of droplet size, impact energy, & various ambient conditions of temperature, pressure, & relative humidity. Effects of electric & sonic fields will also be investigated.
Super-Cooled Water Saturation Vapor Pressure			Determine the saturation vapor pressure of super-cooled water.
Adiabatic Cloud Expansion			Duplicate in time & conditions the early portion of the life cycle of a parcel of air involved in an atmospheric precipitation process.
Ice Nuclei Memory			Determine the effect of an ice nuclei's history on its ability to initiate (nucleate) the ice phase.
Terrestrial Expansion Chamber Evaluation			Measure condensation & ice nuclei activation efficiencies under operating conditions similar to those utilized in terrestrial laboratories, but without gravity-included convection.

PRINCIPAL PHYSICAL PROPERTY MEASURED, RANGE, ACCURACY, AND RESOLUTION:

ACPL

EI-68

Sensor or Experiment Name	Physical Property Measured/Property Range & Accuracy Resolution	Associated Ranges and/or Resolutions	Purpose, Component Properties, Other Comments
Condensation Nuclei Memory			Determine the effect of a condensation nuclei's history on its ability to initiate (nucleate) the liquid phase.
Nuclei Multiplication			Determine the processes & extent of nuclei material breakup.
Drop Collision Breakup (>0.5 mm)			Determine the energy requirements of large droplet-droplet collision-induced breakup as a function of fluid properties, droplet diameters, & external field conditions (sound & electrical).
Coalescence Efficiencies (<100 μm)			Determine the coalescence efficiencies of small (>50 μm) cloud droplets under varying impact conditions with specific attention toward what happens at the droplet-droplet interface just before & during collision.
Static Diffusion Chamber Evaluation			Determine the absolute nucleation efficiencies of standarized nuclei sources utilizing zero fallout conditions.

PRINCIPAL PHYSICAL PROPERTY MEASURED, RANGE, ACCURACY, AND RESOLUTION:

ACPL EI-68

Sensor or Experiment Name	Physical Property Measured/Property Range & Accuracy Resolution	Associated Ranges and/or Resolutions	Purpose, Component Properties, Other Comments
Unventilated Droplet Diffusion Coefficient			Determine the undisturbed diffusion (nonconvective) heat & mass transfer coefficient for growing & evaporating droplets (diameter >10 μm) under various conditions of temperature, pressure, & relative humidity & for various droplet diameters. This class of experiments will include the effects of various atmospheric contaminants on these coefficients.

COMMUNICATIONS

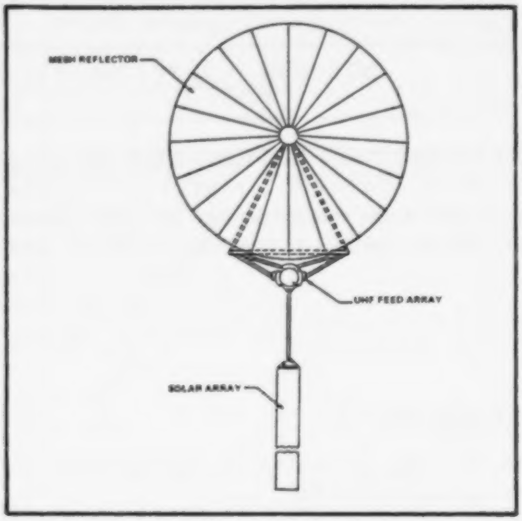
The Communications program consists of two major elements: (1) increased support of spacecraft instrument data in the form of 85% coverage of low earth orbits, augmentation of deep space probe data capabilities, and data processing enhancements to satellite data streams; and (2) the technology for the growth of satellite communications requiring long-term, high-risk, and higher cost technology development.

COMMUNICATIONS MISSIONS

NO.	
C-6	Multi-Service Thin Route Narrowband Program will establish the technology for UHF communications such as emergency and disaster communications, automatic data platforms, and land-mobile voice communications.
C-7	Tracking and Data Relay Satellite (TDRSS-II) would have improved capabilities over TDRSS-I.
C-8	Orbiting Deep Space Relay Station is to provide deep space tracking and communications support of deep space probes.

MISSION: Multi-Service Thin Route Narrowband Program C-6

Status:	Opportunity
Lifetime:	7-10 years
Launch and Transfer Vehicles:	Shuttle/IUS
Operational Location:	Geosynchronous
Total Mass at Operational Location:	2300 kg
Average Operational Power:	10 kW



OBJECTIVE:

To demonstrate satellite technology for primarily narrowband communications in the UHF S-band spectrum for fixed and mobile users in a large number of applications. To provide sufficient channel capacity to demonstrate the economic viability of a commercial system.

DESCRIPTION:

Envisioned is a communication satellite providing the high gain and power which is necessary to provide links to small, generally mobile, terminals in the UHF-S band spectrum. The range of applications includes public safety, general education, emergency medical care, energy management, transportation, mobile telephone, position location, information retrieval, health care, disaster relief, search and rescue, and others where narrow bandwidth is sufficient and small ground stations are necessary. The most commercially viable application appears today to be the completion of the mobile telephone networks by providing links to thinly populated areas where the satellite may offer a cost effective alternative to the terrestrial networks. In a broader sense, the satellite would provide an opportunity for developing reliable and rapid communications anywhere within a wide geographical area where such communication is limited or does not exist.

Suitable satellite systems are roughly characterized by a large antenna (14-50 m), high power (1-5 kW RF), and a large number of beams (20-70). These characteristics are a significant advance beyond existing practice and thus are viewed as new technology.

CRITICAL TECHNOLOGY NEEDS:

Large, multibeam, offset feed antennas; long-life high power RF sources; high power photovoltaics for geosynchronous use; ability to control a flexible structure to maintain the beam quality and line of sight.

MISSION: Multi-Service Thin Route Narrowband Program C-6

INSTRUMENT OR EXPERIMENT COMPLEMENT:

Extensive instrumentation of the spacecraft and antenna structure to observe mechanical behavior in the thermal and dynamic environment.

REFERENCES:

NASA HQ, EC, Briefing on Multi-service/Mobile Satellite Thin Route Communications, 9 April 1980

CONTACTS:

G. Knouse, NASA HQ, ECE-4, 202/755-8570

COMMUNICATIONS

MISSION TECHNOLOGY REQUIREMENTS

MISSION: Multi-Service Thin Route Narrowband Program C-6

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Physical Character			
Overall dimensions (m)	14-50	2, REV	Antenna diameter. Other dimensions scalable from figure. However, solar array should be sized based on power needed. Radiators are conspicuously absent in figure.
Total Mass (kg)	2300	2, SOA	Limited by capability of IUS.
Deployed items, size (m)			See figure to envision the several items which would require deployment: antenna, antenna support, solar arrays.
1.			
2.			
Life			
Flight duration (yr)	7-10	2, EV	Long-life is required to support demonstration of commercial market viability.
Number of spacecraft	2	3	A second vehicle is deemed desirable to provide the additional service assurance required for demonstration of commercial viability.
Orbit			
Altitude (km)			Geosynchronous at approximately 120° W.
Inclination (deg)			

COMMUNICATIONS

MISSION TECHNOLOGY REQUIREMENTS

MISSION: Multi-Service Thin Route Narrowband Program C-6

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Data	Not defined yet. Satellite transponders will use analog FM to be compatible with projected user equipments. They will also have capability for transponding digital streams. Although the number of beams is large, it is possible that significant switching between beams will not be necessary because many applications require only establishing a link within a beam.		
Spacecraft processors/ computers			
I/O rates (bps)			
Memory size (bits)			
Speed (ops/sec)			
Guidance & Attitude Control			
Position accuracy (km)	±0.1° stationkeeping, based on recommended ITU regulations.		
Pointing accuracy (mrad)	0.8	1	Based on 800 MHz 50-m antenna, 0.5° half-power beam, 1/10 beamwidth criteria. Other accuracy and stability requirements calculable from half-power beamwidth = 1.2 λ/D. Assume stability rms value is 1/10 of pointing accuracy. Beam line of sight is to remain within 1/10 of half-power beamwidth about a desired beam center point on earth.
Stability (mrad)	0.08	2	
Type of control system	ND		

COMMUNICATIONS
MISSION TECHNOLOGY REQUIREMENTS

MISSION: Multi-Service Thin Route Narrowband Program C-6

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Power			
Average power consumed (kWe)	10	3, EV	
Peak power consumed (kWe)			No significant peaking
Power breakdown (We)	ND		
Communications			
Link, type of data and rate (Mbps)	duplex		Duplex links are probable for mobile telephone applications
Frequency (GHz)	in 0.8-0.9 band for mobile telephone		0.4 for data collection applications; 2.5 for one-way video links with voice return; mobile telephone applications would use 50-70 beams uniformly spread over CONUS, Hawaii; number of beams expandable to reach other regions of western hemisphere; a 3-frequency pattern of beams is envisioned, but sufficient beam separation may not be achievable with current SOA in sidelobe control.
Bandwidth (MHz)	10 MHz for mobile telephone		30 kHz each voice channel
RF power from satellite (W)	1 for mobile telephone		Per 30 kHz voice channel in a 0.5° half-power beamwidth 10 MHz beam
G/T (dB/K)	-16 to -22		This G/T range is typical of values envisioned for mobile telephone application. Ground antenna gain is strong design driver, but more than 8-10 dB is not deemed desirable.

COMMUNICATIONS

MISSION TECHNOLOGY REQUIREMENTS

MISSION: Multi-Service Thin Route Narrowband Program C-6

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Thermal Control			
Component temperature (K)			No known requirements which are unusual
1.			
2.			
3.			
Component load (Wt)			
1.			
2.			
3.			
Propulsion			
Total ΔV required (m/sec)			
Thrust level (N)			
I_{sp} of stages (sec)			

COMMUNICATIONS

MISSION: Tracking and Data Relay Satellite -II (TDRSS-II) C-7

Status: Opportunity

Lifetime:

Launch and Transfer Vehicles:

Operational Location:

Total Mass at Operational Location:

Average Operational Power:

OBJECTIVE: TDRSS-II or Second Generation TDRSS or follow-on TDRSS are terms which apply to the combination ground terminal and spacecraft that could result from an advanced study sponsored by OSTDS that is now under way at GSFC. The objective of the advanced study is to define a reasonable set of NASA mission support requirements; the candidate concepts that could reasonably meet these predicted T&DA support needs after the current TDRSS era; make trade-offs, recommend plans, and identify critical new technology that must be first pursued.

DESCRIPTION: The TDRSS-II that results from our advanced studies would have improved capabilities over TDRSS-I, e.g., more and wider bandwidth links to the user and a TDRSS-to-TDRSS space data link. Its basic description and whether or not it becomes a candidate NASA program will depend, at least, on the outcome of our pre-Phase A studies.

CRITICAL TECHNOLOGY NEEDS:

INSTRUMENT OR EXPERIMENT COMPLEMENT:

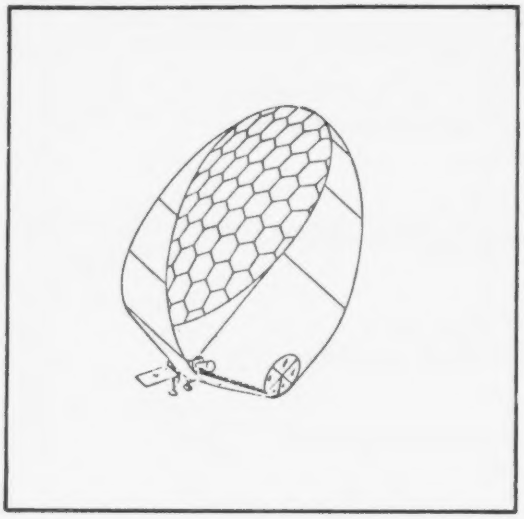
REFERENCES:

CONTACTS:

R. Aller, NASA Headquarters, TX-1

MISSION: Orbiting Deep Space Relay Station (ODSRS) C-8

Status:	Opportunity
Lifetime:	10 years
Launch and Transfer Vehicles:	Shuttle/OTV
Operational Location:	GEO
Total Mass at Operational Location:	8500 kg
Average Operational Power:	5.5 kW



OBJECTIVE:

To provide deep space tracking and communications support of deep space probes in the post 1985 era.

DESCRIPTION:

The ODSRS conceptual design is a 28 m, offset feed, two-reflector Cassegrain antenna. It has a lighweight deployable backup structure with precision surface panels attached in low-earth orbit, using the Shuttle as a work platform. Support subsystems for the ODSRS are contained in a boxlike bus attached to the main antenna backup structure. The estimated ODSRS mass is 8500 kg, and its stowed volume is approximately 2 Shuttle cargo bays. The orbit transfer vehicle to boost the ODSRS from Shuttle orbit to synchronous orbit will require a third Shuttle flight. ODSRS power consumption is estimated to be 5.5 kW, most of which will be a continuous load for refrigerators for the cryogenic receivers.

CRITICAL TECHNOLOGY NEEDS:

INSTRUMENT OR EXPERIMENT COMPLEMENT:

REFERENCES:

J. A. Hunter, Orbiting Deep Space Relay Study Final Report, JPL 79-30

CONTACTS:

Hugh Fosque, NASA HQ, TS-1
J. Hunter, JPL

COMMUNICATIONS

MISSION TECHNOLOGY REQUIREMENTS

MISSION: Orbiting Deep Space Relay Station (ODSRS) C-8

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Physical Character			
Overall dimensions (m)	28		Diameter of antenna
Total Mass (kg)	8443		
Structure	4709		
Telecommunications	629		
Power	579		
Att. control	299		
Propulsion	470		
Thermal control	1757		
Deployed items, size (m)			
1.			
2.			
Life			
Flight duration (days)	3653		
Number of spacecraft	1		
Orbit			
Altitude (km)	35,786		
Inclination (deg)	0		Small inclinations are permissible.

COMMUNICATIONS

MISSION TECHNOLOGY REQUIREMENTS

MISSION: Orbiting Deep Space Relay Station (ODSRS) C-8

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Data			
Spacecraft processors/ computers	STACC		For command and control
I/O rates (bps)			
Memory size (bits)			
Speed (ops/sec)			
Guidance & Attitude Control			
Position accuracy (cm)	10		Single axis
Pointing accuracy (mrad)	0.35		
Stability (mrad)			
Type of control system			Celestial, inertial, antenna beam error sensors

COMMUNICATIONS
MISSION TECHNOLOGY REQUIREMENTS

MISSION: Orbiting Deep Space Relay Station (ODSRS) C-8

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Power			
Average power consumed (kWe)	5.5		"KIPS", organic Rankine cycle power conversion system using plutonium oxide heat source.
Peak power consumed (kWe)			
Power breakdown (We)			
Energy Storage			
Storage type	NA		
Energy/cycle (J)			
Communications			
Link, type of data and rate (Mbps)	DSN digital 25 kpbs - 25 Mbps/TT&C		DOWNLINK/UPLINK
Frequency (GHz)	14/2.2		DOWNLINK/UPLINK
Bandwidth (MHz)	5-50		
RF power (W)	0.001-3		
Noise temperature (K)	366.1/98		DOWNLINK/UPLINK
Gain (dB)	55.76/39.13		DOWNLINK/UPLINK
Beam Number	1		

COMMUNICATIONS

MISSION TECHNOLOGY REQUIREMENTS

MISSION: Orbiting Deep Space Relay Station (ODSRS) C-8

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Thermal Control			
Component temperature (K)			
1.			
2.			
3.			
Component load (Wt)			
1.			
2.			
3.			
Propulsion			
Total ΔV required (m/sec)	60		N_2H_4 2:1 blowdown
Thrust level (N)	0.9/5		attitude/stationkeeping
I_{sp} of stages (sec)	175/215		

SPACE TRANSPORTATION

The Space Transportation program objective is to provide vehicles to transport missions to their desired destination, either in earth orbit or elsewhere in the solar system and beyond. The current program utilizes expendable vehicles which will be largely replaced by the Space Shuttle. Future emphasis will be on vehicles which extend the basic Shuttle launch capability by providing improvements in payload, cost, and servicing for ranges and duration outside the Shuttle performance envelope.

SPACE TRANSPORTATION MISSIONS

No.	
T-13	Heavy-Lift Launch Vehicle is a launch vehicle capable of carrying unmanned payloads of 60-450 metric tons to LEO.
T-14	Advanced Electric Propulsion
T-15	Unconventional Orbital Transfer Vehicle

TRANSPORTATION

MISSION: Heavy-Lift Launch Vehicle (HLLV) T-13

Status:	Opportunity
Lifetime:	
Launch and Transfer Vehicles:	
Operational Location:	500 km
Total Mass at Operational Location:	Up to 450,000 kg
Average Operational Power:	

OBJECTIVE:

To identify requirements and develop specifications for launch vehicles capable of carrying unmanned payloads into low-earth orbit which are heavier (60 to 450 metric tons) than Shuttle payloads.

DESCRIPTION:

Studies indicate that up to 84,000 kg payloads can be accommodated by an unmanned HLLV configuration that employs the present External Tank, a recoverable capsule with three SSMEs, and an expendable payload shroud/strongback. Liquid rockets in lieu of the present SRBs would be required. Heavier payloads would require a new HLLV stage having little in common with the present STS.

CRITICAL TECHNOLOGY NEEDS:

Expendable hardware needs to be eliminated or reduced. Landing modes of reusable boosters need further development.

INSTRUMENT OR EXPERIMENT COMPLEMENT:

Many candidate payloads/missions contemplated.

REFERENCES:

Systems Concepts for STS-Derived Heavy Lift Launch Vehicle Study, Vol. 1-4, Boeing Aerospace Co. for NASA/MSFC (contract NAS9-14710), September 1976.

CONTACTS:

L. Edwards, NASA HQ., MTC-3

TRANSPORTATION

MISSION TECHNOLOGY REQUIREMENTS

MISSION: Heavy-Lift Launch Vehicle (HLLV) T-13

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Physical Character			
Overall dimensions (m)	53		Shuttle-derived version
Total mass (kg)	1.9×10^6		Lift-off weight incl. payload
Usable propellant mass (kg)	$.85 \times 10^6$ $.70 \times 10^6$		Liquid strap-ons ET
Deployed items, size (m)			
1.			
2.			
Payload Capability			
Mass (kg)	84,000		
Volume (m^3)	1000		Up to 7 m dia × 20-25 m long
Life			
Flight duration			Mainly used for expendable launch to LEO.
Number of spacecraft			
Orbit			
Altitude (km)	200-500		Typical
Inclination (deg)	Various		

TRANSPORTATION
MISSION TECHNOLOGY REQUIREMENTS

MISSION: Heavy-Lift Launch Vehicle (HLLV) T-13

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Thermal Control (Cont.)			
Component load (Wt)			
1.			
2.			
3.			
Propulsion			
Total impulse (N-sec)			Liquid strap-on boosters may use SSME with nozzle reduced to 35:1 expansion ratio, or new hydrocarbon engine may be justified.
Restarts (no.)			
Stages (no.)			
Type of propellant			
I_{sp} of stages (sec)			
1.			
2.			
3.			
Thrust of stages (N)			
1.			
2.			
3.			

TRANSPORTATION

MISSION: Advanced Electric Propulsion T-14

Status:	Opportunity
Lifetime:	TBD
Launch and Transfer Vehicles:	Deep space: None or OTV Earth: None or Low Thrust Liquid (LTL)
Operational Location:	
Total Mass at Operational Location:	TBD
Average Operational Power:	>50 kW to MWs

OBJECTIVE:

Deep space: Transport high C_3, high mass science spacecraft to outer planets
Earth: LEO to GEO transport

DESCRIPTION:

Deep space: nuclear reaction driven thermionic or thermoelectric conversion devices provide direct power for high voltage/current elements of electric thrusters

Earth: Scaled up SEPS, possibly with magnetoplasmadynamic (MPD), rather than ion thrusters, using noble gasses (e.g., Argon) rather than Mercury.

CRITICAL TECHNOLOGY NEEDS:

Deep space: Reactors, conversion devices, direct drive thrusters
Earth: Large structures, high voltage solar powered systems, low I_{sp} thrusters, radiation resistant solar cells, noble gas thrusters

INSTRUMENT OR EXPERIMENT COMPLEMENT:

REFERENCES:

CONTACTS:

W. Kisko, NASA HQ, MTG-3

TRANSPORTATION

MISSION TECHNOLOGY REQUIREMENTS

MISSION: Advanced Electric Propulsion T-14

Mission Parameter (units)	Value		Confidence Level, Technology State	Comments
Physical Character	D	E		D: deep space E: earth
Overall dimensions (m)				
Total mass (kg)				
Usable propellant mass (kg)				
Deployed items, size (m)				
1.				E: multi 100 kW to MW solar array
2.				
Payload Capability				
Mass (kg)	$<10^4$	$>10^4$		
Volume (m^3)				D: STS volume limit E: large structures up to SPS size
Life				
Flight duration (days)	<1 yr	>1 yr		
Number of spacecraft				
Orbit				
Altitude (km)				D: earth escape E: LEO to GEO
Inclination (deg)				

TRANSPORTATION

MISSION TECHNOLOGY REQUIREMENTS

MISSION: Advanced Electric Propulsion T-14

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Power	D E		
Average power consumed (kWe)			
Peak power consumed (kWe)			D: <MW E: 100 kW to MWs
Power breakdown (We)			
Energy Storage			
Storage type			No primary storage
Energy/cycle (J)			
Communications			
Link, type of data and rate (Mbps)	TBD		
Thermal Control			
Component temperature (K)			D: typical 775 K radiator temperature >1400 K core heat pipe temperature
1.			
2.			
3.			

TRANSPORTATION

MISSION TECHNOLOGY REQUIREMENTS

MISSION: Advanced Electric Propulsion T-14

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Thermal Control (Cont.)			
Component load (Wt)	TBD		
1.			
2.			
3.			
Propulsion			
Total impulse (N-sec)			
Restarts (no.)	few $>10^3$		
Stages (no.)	1 1		Potential chemical boost stage (OTV or LTL)
Type of propellant			Thruster dependent, Argon or Mercury
I_{sp} of stages (sec)			
1.			D: 3000+ E: 1000
2.			
3.			
Thrust of stages (N)			
1.			Thruster dependent
2.			
3.			

TRANSPORTATION

MISSION: Unconventional Orbital Transfer Vehicle T-15

Status: Opportunity

Lifetime:

Launch and Transfer Vehicles:

Operational Location:

Total Mass at Operational Location:

Average Operational Power:

OBJECTIVE:

To provide new space propulsion/transfer capabilities beyond the current and near term "conventional" techniques.

DESCRIPTION: As high energy missions and large payloads develop, there will be an increasing need for greater performance capability and improved efficiency and economy of operation in upper/transfer stages. High-performance, chemical rocket upper stages with capability for recovery and reuse are currently under study ("Orbit Transfer Vehicle" studies), as are "low-thrust" versions of chemical rocket upper stages for potential use with acceleration-limited payloads. More advanced propulsive systems might be viable candidates for such missions in the post 1990 time period. This study shall be on systems with vehicle and propulsion system definition undertaken in sufficient depth to lend credence to the entire concept, including all supporting elements. This survey and examination is to include the following concepts, plus other appropriate systems that may be identified during the course of the study: (1) working fluid heated or augmented by external source (solar concentrator, space-based laser, ground-based laser, and nuclear); (2) advanced electric [ion bombardment, magnetoplasmadynamic (MPD), microwave or rf discharge (free radical rocket), propellant other than mercury, large thrusters, higher thrust/weight, nuclear thermodynamic, and nuclear thermoelectric]; and (3) other (electromagnetic launcher and space cranes using tethers).

CRITICAL TECHNOLOGY NEEDS :

Many and varied

INSTRUMENT OR EXPERIMENT COMPLEMENT:

REFERENCES:

CONTACTS

L. Edwards, NASA HQ, MTG-3

UTILIZATION OF THE SPACE ENVIRONMENT

The Utilization of the Space Environment program objectives include research and experimentation in materials processing and space biology, space industrialization, space power, platforms, and nonterrestrial materials utilization. The near-term emphasis is on initiation of Spacelab and free-flier missions to develop the complex space systems and operations required for exploiting the characteristics of space, such as weightlessness and ultrahigh vacuum. The far-term emphasis will be on commercial scale operations in earth orbit and perhaps in the lunar vicinity.

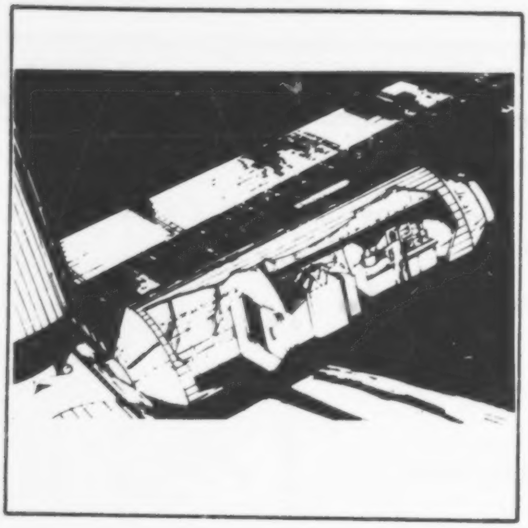
Utilization of the Space Environment Missions

NO.	
U-12	Materials Experimentation Module is envisioned as a habitable laboratory designed to support materials R&D.
U-13	Space Power Technology Demonstration is an engineering verification of several technologies that are considered critical to the space power system.
U-14	Space Operational Center (SOC) is a Shuttle-serviced, permanently manned facility in near space.

UTILIZATION OF SPACE ENVIRONMENT

MISSION: Materials Experimentation Module (MEM) U-12

Status:	Opportunity
Lifetime:	
Launch and Transfer Vehicles:	Shuttle/spacelab
Operational Location:	LEO
Total Mass at Operational Location:	
Average Operational Power:	20-30 kW



OBJECTIVE:

The objective of the MEM is to support those types of Material Processing Systems (MPS) R&D that require intimate manned participation.

DESCRIPTION:

MEM will be the next evolutionary step in the spacelab type of module and is now envisioned to be about 6 m long and 4.6 m in diameter. MEM will accommodate high technology crystal, metallurgical, and biological R&D equipment such as furnaces, electrophoretic separation equipment. Studies are yet to be done on this system in detail.

CRITICAL TECHNOLOGY NEEDS:

Long life, high reliability systems; resource recovery/recycle equipment; power and heat rejection; contactless heating equipment; mixing equipment

INSTRUMENT OR EXPERIMENT COMPLEMENT:

Furnaces, electrophoretic separation equipment

REFERENCES:

J. Carruthers, NASA HQ, EM-7
L. Zoller, MSFC, 205/453-0542

CONTACTS:

J. Carruthers, NASA HQ, EM-7
M. Nolan, NASA HQ, MTC-3

UTILIZATION OF SPACE ENVIRONMENT

MISSION TECHNOLOGY REQUIREMENTS

MISSION: Materials Experimentation Module (MEM) U-12

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Physical Character			
Overall dimensions (m)	6 × 4.6		L × D
Total mass (kg)			
Deployed items, size (m)			
1.			
2.			
Life			
Flight duration (days)			A permanent basic structure with refitting of equipment
Number of spacecraft			
Reliability	0.97		For 90 days (composite)
Orbit			
Altitude (km)			Shuttle revisit altitudes
Inclination (deg)			

UTILIZATION OF SPACE ENVIRONMENT

MISSION TECHNOLOGY REQUIREMENTS

MISSION: Materials Experimentation Module (MEM) U-12

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Data			
Data volume (bits/day)			
Storage capacity (bits)			
I/O rates (bps)			
Spacecraft processors/ computers			
I/O rates (bps)			
Memory size (bits)			
Speed (ops/sec)			
Ground Processors/ computers			
Memory size (bits)			
Guidance & Attitude Control			
Position accuracy (km)			
Pointing accuracy (mrad)			
Stability (g)	10^{-5}	2, EV	$>10^{-5}$ g level is not to be experienced by experiments for any appreciable time
Type of control system			

UTILIZATION OF SPACE ENVIRONMENT

MISSION TECHNOLOGY REQUIREMENTS

MISSION: Materials Experimentation Module (MEM) U-12

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Power			
Average power consumed (kWe)	25		25-kW power module
Peak power consumed (kWe)			
Power breakdown (We)			
Energy Storage			
Storage type			
Energy/cycle (J)			
Communications			
Link, type of data and rate (Mbps)			
Special			
Mixing equipment			Eliminate voids; gain melt homogenization
Resource recovery/ recycle equipment			Clean water to FDA standards

UTILIZATION OF SPACE ENVIRONMENT

MISSION TECHNOLOGY REQUIREMENTS

MISSION: Materials Experimentation Module (MEM) U-12

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Thermal Control			
Component temperature (K)			
1. Heat pipe	278/317		In/out
2.			
3.			
Component load (Wt)			
1.			
2.			
3.			
Propulsion			
Total ΔV required (m/sec)	NA		
Thrust level (N)			
I_{sp} of stages (sec)			

UTILIZATION OF SPACE ENVIRONMENT

MISSION: Space Power Technology Demonstration U-13

Status: Opportunity

Lifetime:

Launch and Transfer Vehicles: Shuttle/?

Operational Location: GEO

Total Mass at Operational Location: ND

Average Operational Power: 100 kW to MWs

OBJECTIVE:

The objective of this mission is the engineering verification of several technologies that are considered critical to the Space Power System. Fabrication and assembly of large space structures and continuous microwave transmission of a large amount of power from space are key elements of this demonstration.

DESCRIPTION:

An experimental shuttle payload consisting of several SPS structural elements, a solar array, a >100 m antenna, and power control subsystem would be deployed in low earth orbit. Boosted to GEO, the demonstration unit would continuously transmit approximately 1 MW of microwave power to a ground station. Data on pilot beam interaction, phase control, beam formation, beam coherence and environmental factors, and space construction operations would be obtained. NOTE: The SPS is a concept for a space system with near continuous sun exposure for producing power to beam to terrestrial networks. Base-line system is 5 GWe DC at output of ground rectennas with photovoltaic conversion in space. Solar flux to terrestrial DC overall efficiency is 7%. Major elements of base line are 50 km^2 array size, 1 km dia 2.5 GHz transmitter using $1\text{-}2 \times 10^5$ klystrons, satellite mass of $30\text{-}50 \times 10^6$ kg, ground rectenna size 10 × 13 km with 25 billion rectifier elements.

CRITICAL TECHNOLOGY NEEDS:

Fabrication, assembly, and deployment of large structures in space. Design of several elements of large microwave power transmitters.

INSTRUMENT OR EXPERIMENT COMPLEMENT:

REFERENCES:

CONTACTS:

W. Kisko, MTG-3

UTILIZATION OF SPACE ENVIRONMENT

MISSION TECHNOLOGY REQUIREMENTS

MISSION: Space Power Technology Demonstration U-13

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Physical Character			
Overall dimensions (m)			
Total mass (kg)			
Deployed items, size (m)			Sizes and masses will vary considerably dependent on major test objectives.
1. Microwave antenna	>100		
2. Solar arrays	>10 × 100		L × W
Life			
Flight duration (days)			
Number of spacecraft			
Orbit			
Altitude (km)			Initial fabrication and assembly in LEO. Operated in LEO or boosted to operational location in GEO.
Inclination (deg)			

UTILIZATION OF SPACE ENVIRONMENT

MISSION TECHNOLOGY REQUIREMENTS

MISSION: Space Power Technology Demonstration U-13

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Power			
Average power consumed (kWe)			100 kW to MWs
Peak power consumed (kWe)			
Power breakdown (We)			
Energy Storage			
Storage type			
Energy/cycle (J)			
Communications			
Link, type of data and rate (Mbps)			

UTILIZATION OF SPACE ENVIRONMENT

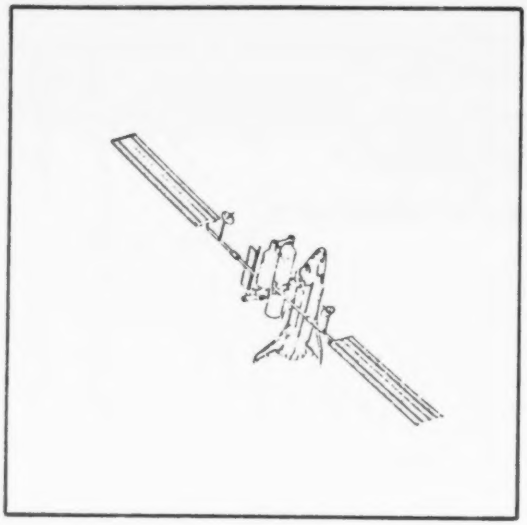
MISSION TECHNOLOGY REQUIREMENTS

MISSION: Space Power Technology Demonstration U-13

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Thermal Control			
Component temperature (K)			
1.			
2.			
3.			
Component load (Wt)			
1.			
2.			
3.			
Propulsion			
Total ΔV required (m/sec)	TBD		Ion thruster for transfer from LEO to GEO
Thrust level (N)			
I_{sp} of stages (sec)			

MISSION: Space Operational Center (SOC) U-14

Status:	Opportunity
Lifetime:	90-180 day re-supply
Launch and Transfer Vehicles:	Shuttle
Operational Location:	LEO
Total Mass at Operational Location:	
Average Operational Power:	18 kW



OBJECTIVE:

The Space Operational Center is a Shuttle-serviced, permanently manned facility in near space for operational support of space activities in the late 1980s and 1990s.

DESCRIPTION:

Shuttle-launched, modular buildup; multiple docking and berthing ports; capable of operating continuously (with resupply and orbit maintenance); normally manned, but continuous manning not required; continuous Shuttle presence not required (systems and habitat redundance); 90 day normal resupply (additional 90 day emergency provisions); dual access between habitable modules; shirt sleeve transfer between modules.

CRITICAL TECHNOLOGY NEEDS:

INSTRUMENT OR EXPERIMENT COMPLEMENT:

REFERENCES:

Space Operations Center, presentation to NASA Planning Council by JSC, 5 June 1979.

CONTACTS:

R. Freitag, NASA HQ, MT-3

UTILIZATION OF SPACE ENVIRONMENT
MISSION TECHNOLOGY REQUIREMENTS

MISSION: Space Operational Center (SOC) U-14

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Physical Character			Supply: non-depletable power generation
Overall dimensions (m)			recycle air, water onboard health maintenance
Total mass (kg)			Monitor/control: monitor, fault isolation, failure analysis guidance and navigation data bases
Deployed items, size (m)			
1.			Core elements - 8 people: solar array antenna
2.			radiator RCS boom airlock service modules habitation modules logistics module
Life			
Flight duration (days)	90-180		Typical operations: solar array construction stage assembly
Number of spacecraft			OTV servicing
Orbit			
Altitude (km)	LEO		
Inclination (deg)			

UTILIZATION OF SPACE ENVIRONMENT

MISSION TECHNOLOGY REQUIREMENTS

MISSION: Space Operational Center (SOC) U-14

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Data			
Data volume (bits/day)			
Storage capacity (bits)			
I/O rates (bps)			
Spacecraft processors/ computers			
I/O rates (bps)			
Memory size (bits)			
Speed (ops/sec)			
Ground Processors/ computers			
Memory size (bits)			
Guidance & Attitude Control			
Position accuracy (km)			Control moment gyros Reaction control systems
Pointing accuracy (mrad)			
Stability (mrad)			
Type of control system			

UTILIZATION OF SPACE ENVIRONMENT

MISSION TECHNOLOGY REQUIREMENTS

MISSION: Space Operational Center (SOC) U-14

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Power			
Average power consumed (kWe)			Photovoltaic
Peak power consumed (kWe)	18		Continuous
Power breakdown (We)			
Energy Storage			
Storage type			
Energy/cycle (J)			
Communications			
Link, type of data and rate (Mbps)			TDRSS, Orbiter, free flyers, EVA Telemetry, voice, TV, text, graphics

UTILIZATION OF SPACE ENVIRONMENT

MISSION TECHNOLOGY REQUIREMENTS

MISSION Space Operational Center (SOC) U-14

Mission Parameter (units)	Value	Confidence Level, Technology State	Comments
Thermal Control			
Component temperature (K)			
1.			
2.			
3.			
Component load (Wt)			
1. Radiators	9000		
2.			
3.			
Propulsion			
Total ΔV required (m/sec)			N_2H_4
Thrust level (N)			
I_{sp} of stages (sec)			

Office of Aeronautics and Space Technology Instruments

NO.	
OI-15	Zero Gravity Combustion Facility
OI-16	Two-Phase Fluid Mechanics and Heat Transfer Facility

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INSTRUMENT: Zero Gravity Combustion Facility OI-15

STATUS: Opportunity

CARRIER:

PHYSICAL AND GENERAL PROPERTIES:

Physical Size (m): $\approx 6.6\ m^3$

Power Requirement (We): 908

Mass (kg): ≈ 981

Data Rate (kbps):

PRINCIPAL PURPOSE AND FEATURES:

To allow the performance of a wide variety of combustion experiments, from rapid burning to long term smoldering, in a low gravity flight environment.

PRINCIPAL PHYSICAL PROPERTY MEASURED, RANGE, ACCURACY, AND RESOLUTION:

ASSOCIATED RANGES AND/OR RESOLUTION:

COMMENTS:

No OAST funding for this facility in FY 80.

SOURCE/CONTACT:

J. Lundholm, NASA HQ, Code RSI

INSTRUMENT: Two Phase Fluid Mechanics and Heat Transfer Facility OI-16

STATUS: Opportunity

CARRIER: Shuttle/Spacelab

PHYSICAL AND GENERAL PROPERTIES:

Physical Size (m): ~1.1 m^3

Power Requirement (We): ND

Mass (kg): ~580

Data Rate (kbps): ND

PRINCIPAL PURPOSE AND FEATURES:

A Spacelab facility used to conduct fundamental fluid dynamics and heat transfer experiments which have application to the acqusition, thermal control, and transfer of cryogenic fluids in space. Specific objectives are to develop an understanding of and mathematical models for reduced gravity physical phenomena such as two-phase flow, forced convection boiling, reorientation fluid dynamics, bubble dynamics, pool boiling and sloshing dynamics.

PRINCIPAL PHYSICAL PROPERTY MEASURED, RANGE, ACCURACY, AND RESOLUTION:

Two-phase flow: quality, flow rate
Forced convection boiling: flow rate, heat flux, g level
Reorientation fluid dynamics: g level, % fill, tank geometry
Bubble dynamics: g level, bubble size
Pool boiling: g level, heat flux, surface geometry
Slosh dynamics: g level, tank geometry, test liquid

ASSOCIATED RANGES AND/OR RESOLUTION:

Data to be collected using high speed photography (0-400 frames/sec), temperature and pressure transducers (STP, and flow meters (0.01-2 rpm).

COMMENTS:

Technical approach is a reusable spacelab facility in a habitable module utilizing a double rack with tankage, plumbing, instrumentation, control and data recording capability. RCS to be used for low g environments.

SOURCE/CONTACT:

J. Lundholm, NASA HQ, Code RSI

2 TECHNOLOGY REQUIREMENTS SUMMARY

This portion of Volume III of the NASA Space Systems Technology Model presents a summary of the technology requirements data contained in all mission system and program descriptions within the earlier sections. The intent is to provide a convenient method for ascertaining the demands upon each technology discipline. The data are presented in tabular form by discipline, and where possible are plotted as a function of start date.

The technology disciplines include: power and electric propulsion; chemical propulsion; materials and structures; information systems; navigation, guidance and control; and automated operations.

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POWER AND ELECTRIC PROPULSION

Average Power Consumed

Peak Power Consumed

Electric Propulsion - Thrust Level

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POWER

Average Power Consumed (kWe)

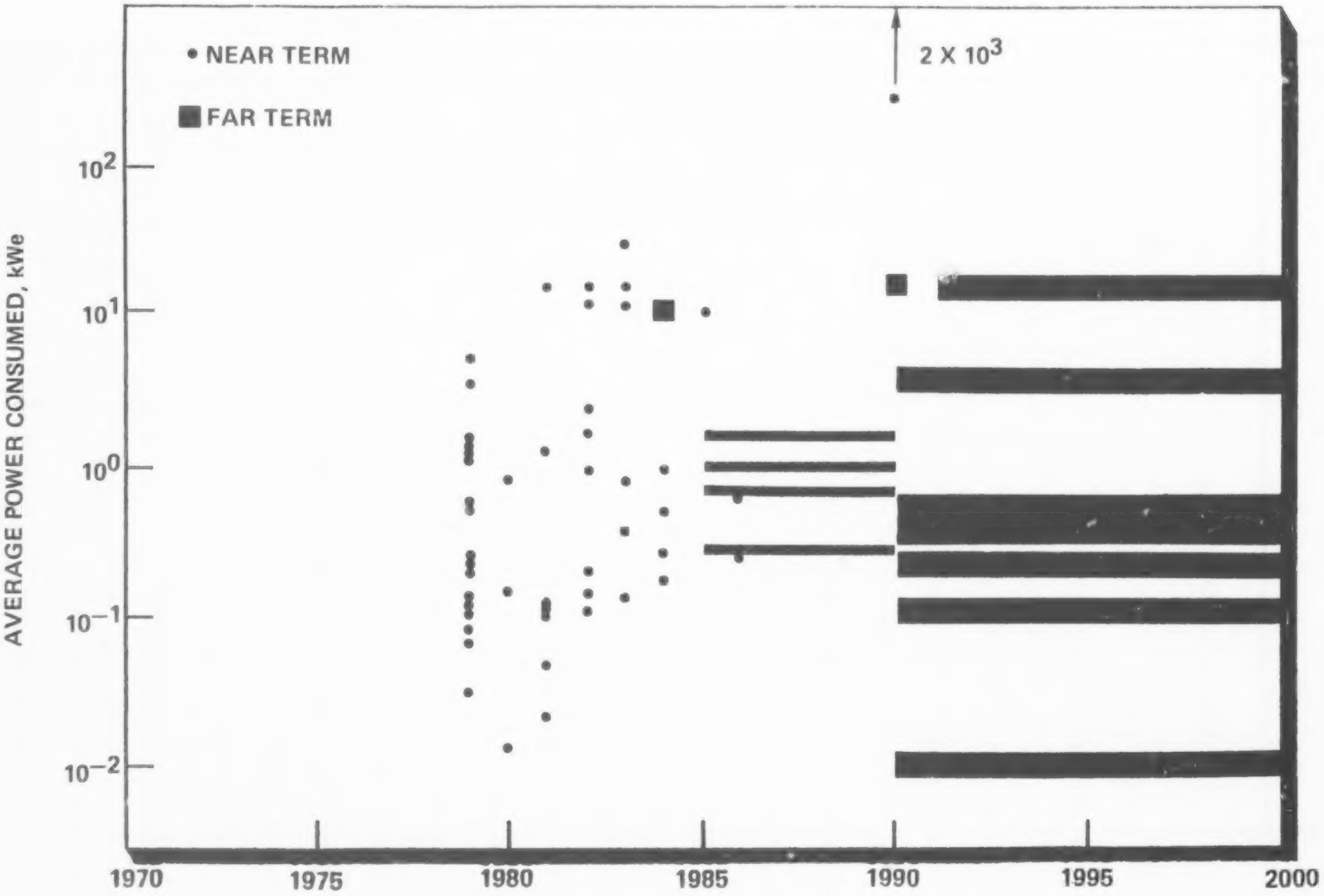
No.	Mission	Value or Range	Technology Readiness Date
C-6	Multi-Service Thin Route Narrowband Program	10	1984
S-14	Pinhole Satellite	ND	>1984
C-7	Tracking and Data Relay Satellite (TDRSS-II)		1986
T-14	Advanced Electric Propulsion	$100-2\times10^3$	1990
T-15	Unconventional Orbital Transfer Vehicle		1990
U-12	Materials Experimentation Module	25	1990
U-13	Space Power Technology Demonstration	$100-2\times10^3$	1990
P-7	Asteroid Multiple Rendezvous	0.7	>1990
P-8	Lunar Polar Orbiter	0.16	>1990
P-9	Mercury Orbiter and Lander	0.3-0.6	>1990
P-10	Comet Sample Return	ND	>1990
P-11	Near Earth Asteroid Sample Return	0.4	>1990
P-12	Venus Lander	0.065	>1990
P-13	Automated Mobile Lunar Surface Survey	0.15-0.4	>1990
P-14	Automated Planetary Station	25.0	>1990
P-15	Lunar Backside Lander and Sample Return	ND	>1990
P-16	Ganymede Lander	0.005-0.01	>1990
A-18	IR Interferometer	25.0	>1990
A-19	Gravity Wave Interferometer	ND	>1990
A-20	Coherent Optical System of Modular Imaging Collectors (COSMIC)	25.0	>1990
A-21	Large Optical/UV Telescope, Diffraction Limited	6.0	>1990

POWER

Average Power Consumed (kWe)

No.	Mission	Value or Range	Technology Readiness Date
A-22	100-m Thinned Aperture Telescope	25.0	>1990
S-15	Close Solar Orbiter	ND	>1990
C-8	Orbiting Deep Space Relay Station	5.5	>1990
L-3	Search for Extraterrestrial Intelligence (SETI)	ND	TBD
T-13	Heavy-Lift Launch Vehicle		TBD
U-14	Space Operational Center (SOC)	18	TBD

TECHNOLOGY REQUIREMENTS SUMMARY



Power: Average Power Consumed

Peak Power Consumed (kWe)

No.	Mission	Value or Range	Technology Readiness Date
C-6	Multi-Service Thin Route Narrowband Program	ND	1984
S-14	Pinhole Satellite		>1984
C-7	Tracking and Data Relay Satellite (TDRSS-II)		1986
T-14	Advanced Electric Propulsion		1990
T-15	Unconventional Orbital Transfer Vehicle		1990
U-12	Materials Experimentation Module		1990
U-13	Space Power Technology Demonstration		1990
P-7	Asteroid Multiple Rendezvous	0.7	>1990
P-8	Lunar Polar Orbiter	0.24	>1990
P-9	Mercury Orbiter and Lander	ND	>1990
P-10	Comet Sample Return	ND	>1990
P-11	Near Earth Asteroid Sample Return	ND	>1990
P-12	Venus Lander	0.072	>1990
P-13	Automated Mobile Lunar Surface Survey	ND	>1990
P-14	Automated Planetary Station	ND	>1990
P-15	Lunar Backside Lander and Sample Return	ND	>1990
P-16	Ganymede Lander	ND	>1990
A-18	IR Interferometer	59.0	>1990
A-19	Gravity Wave Interferometer	ND	>1990
A-20	Coherent Optical System of Modular Imaging Collectors (COSMIC)	ND	>1990
A-21	Large Optical/UV Telescope, Diffraction Limited	12.0	>1990

POWER

Peak Power Consumed (kWe)

No.	Mission	Value or Range	Technology Readiness Date
A-22	100-m Thinned Aperture Telescope	ND	>1990
S-15	Close Solar Orbiter	ND	>1990
C-8	Orbiting Deep Space Relay Station		>1990
L-3	Search for Extraterrestrial Intelligence (SETI)	ND	TBD
T-13	Heavy-Lift Launch Vehicle		TBD
U-14	Space Operational Center (SOC)		TBD

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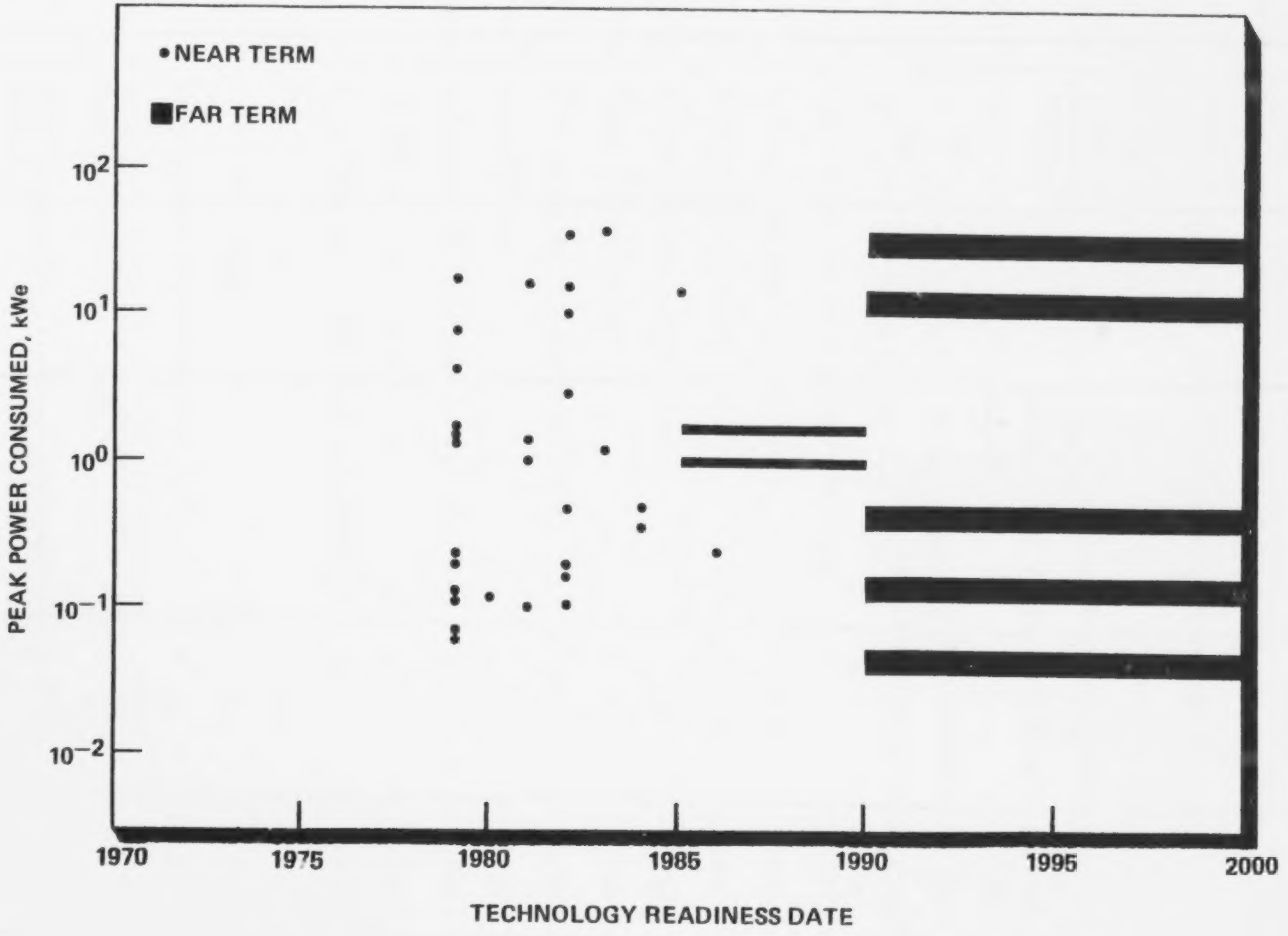
TECHNOLOGY REQUIREMENTS SUMMARY



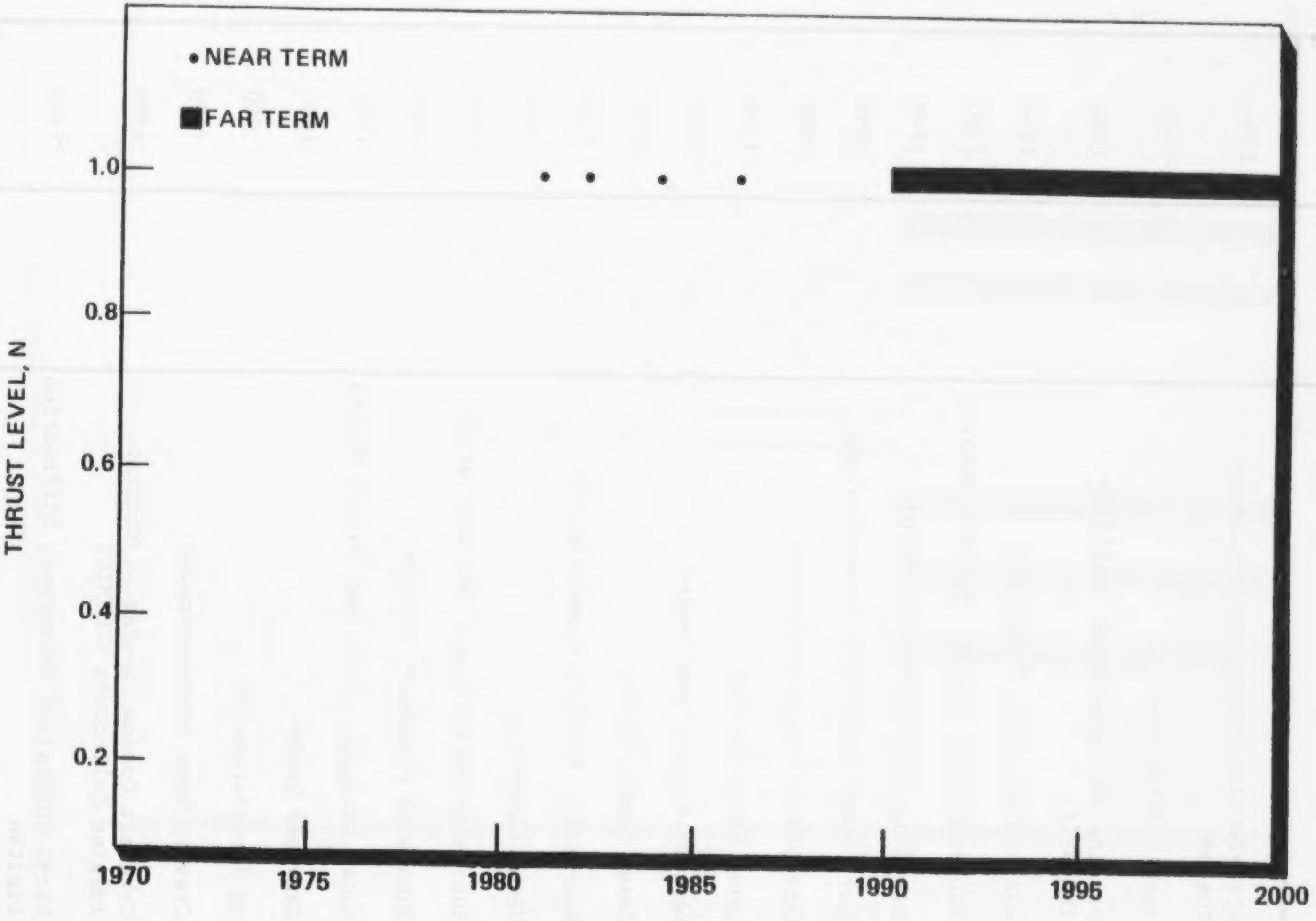
Power: Peak Power Consumed

ELECTRIC PROPULSION

Thrust Level (N)

No.	Mission	Value or Range	Technology Readiness Date
C-6	Multi-Service Thin Route Narrowband Program		1984
S-14	Pinhole Satellite		>1984
C-7	Tracking and Data Relay Satellite (TDRSS-II)		1986
T-14	Advanced Electric Propulsion		1990
T-15	Unconventional Orbital Transfer Vehicle		1990
U-12	Materials Experimentation Module		1990
U-13	Space Power Technology Demonstration		1990
P-7	Asteroid Multiple Rendezvous	<1	>1990
P-8	Lunar Polar Orbiter		>1990
P-9	Mercury Orbiter and Lander	ND	>1990
P-10	Comet Sample Return	<1	>1990
P-11	Near Earth Asteroid Sample Return	<1	>1990
P-12	Venus Lander		>1990
P-13	Automated Mobile Lunar Surface Survey		>1990
P-14	Automated Planetary Station		>1990
P-15	Lunar Backside Lander and Sample Return		>1990
P-16	Ganymede Lander		>1990
A-18	IR Interferometer		>1990
A-19	Gravity Wave Interferometer		>1990
A-20	Coherent Optical System of Modular Imaging Collectors (COSMIC)		>1990
A-21	Large Optical/UV Telescope, Diffraction Limited		>1990

TECHNOLOGY REQUIREMENTS SUMMARY



Electric Propulsion: Thrust Level

CHEMICAL PROPULSION

Thrust Level

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CHEMICAL PROPULSION

Thrust Level (N)

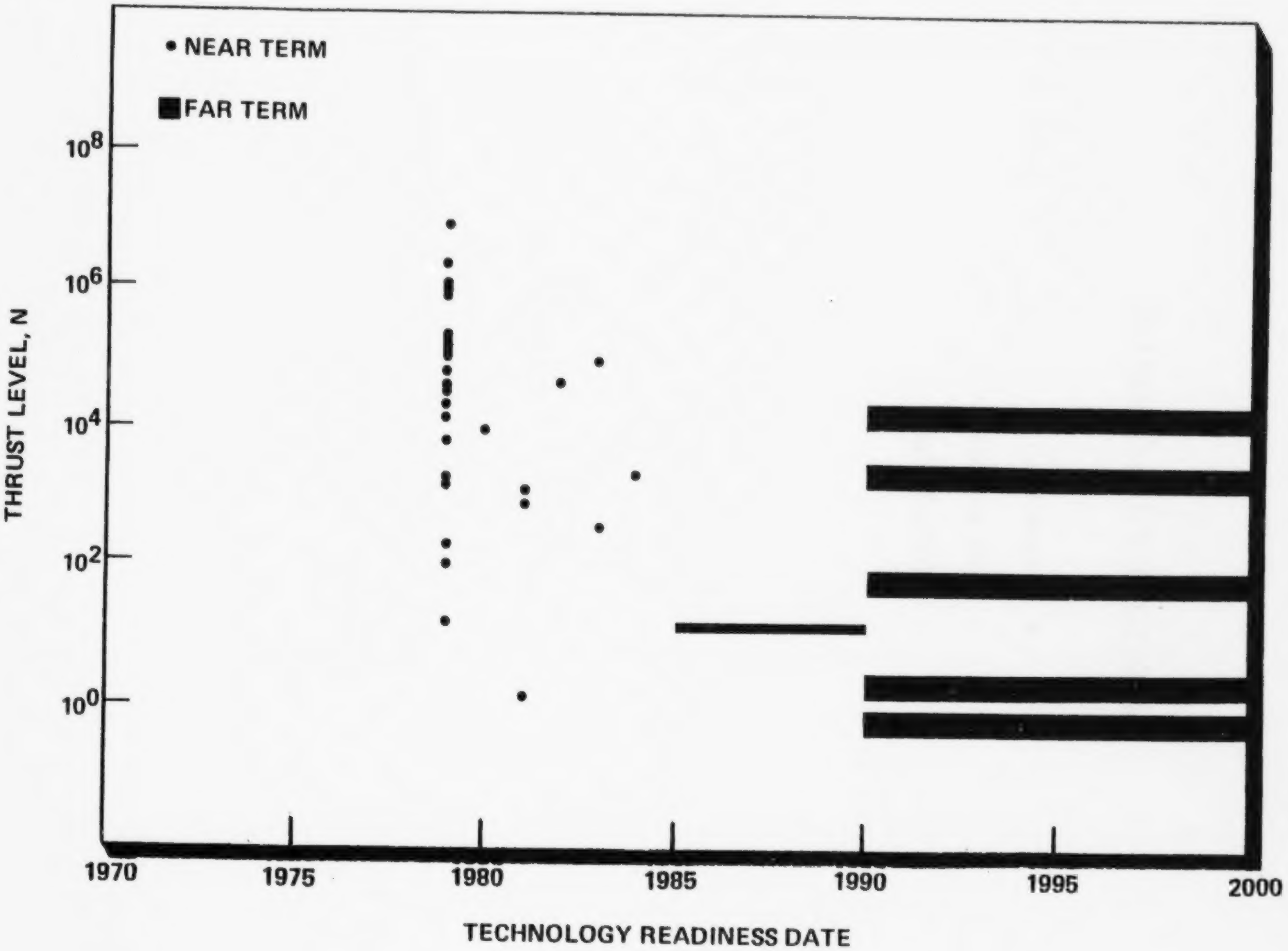
No.	Mission	Value or Range	Technology Readiness Date
C-6	Multi-Service Thin Route Narrowband Program		1984
S-14	Pinhole Satellite	ND	>1984
C-7	Tracking and Data Relay Satellite (TDRSS-II)		1986
T-14	Advanced Electric Propulsion		1990
T-15	Unconventional Orbital Transfer Vehicle		1990
U-12	Materials Experimentation Module		1990
U-13	Space Power Technology Demonstration		1990
P-7	Asteroid Multiple Rendezvous		>1990
P-8	Lunar Polar Orbiter	11,000 (first stage) 88/1 (second stage)	>1990
P-9	Mercury Orbiter and Lander	ND	>1990
P-10	Comet Sample Return	ND	>1990
P-11	Near Earth Asteroid Sample Return	ND	>1990
P-12	Venus Lander	ND	>1990
P-13	Automated Mobile Lunar Surface Survey	ND	>1990
P-14	Automated Planetary Station	ND	>1990
P-15	Lunar Backside Lander and Sample Return		>1990
P-16	Ganymede Lander	18,523 (1st stage) 4640 (2nd stage)	>1990
A-18	IR Interferometer		>1990
A-19	Gravity Wave Interferometer		>1990
A-20	Coherent Optical System of Modular Imaging Collectors (COSMIC)		>1990
A-21	Large Optical/UV Telescope, Diffraction Limited		>1990

CHEMICAL PROPULSION

Thrust Level (N)

No.	Mission	Value or Range	Technology Readiness Date
A-22	100-m Thinned Aperture Telescope		>1990
S-15	Close Solar Orbiter		>1990
C-8	Orbiting Deep Space Relay Station	0.9/5	>1990
L-3	Search for Extraterrestrial Intelligence (SETI)		TBD
T-13	Heavy-Lift Launch Vehicle		TBD
U-14	Space Operational Center (SOC)		TBD

TECHNOLOGY REQUIREMENTS SUMMARY



Chemical Propulsion: Thrust Level

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MATERIALS AND STRUCTURES

Total Mass

Physical Size

Flight Duration

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MATERIALS

Total Mass (kg)

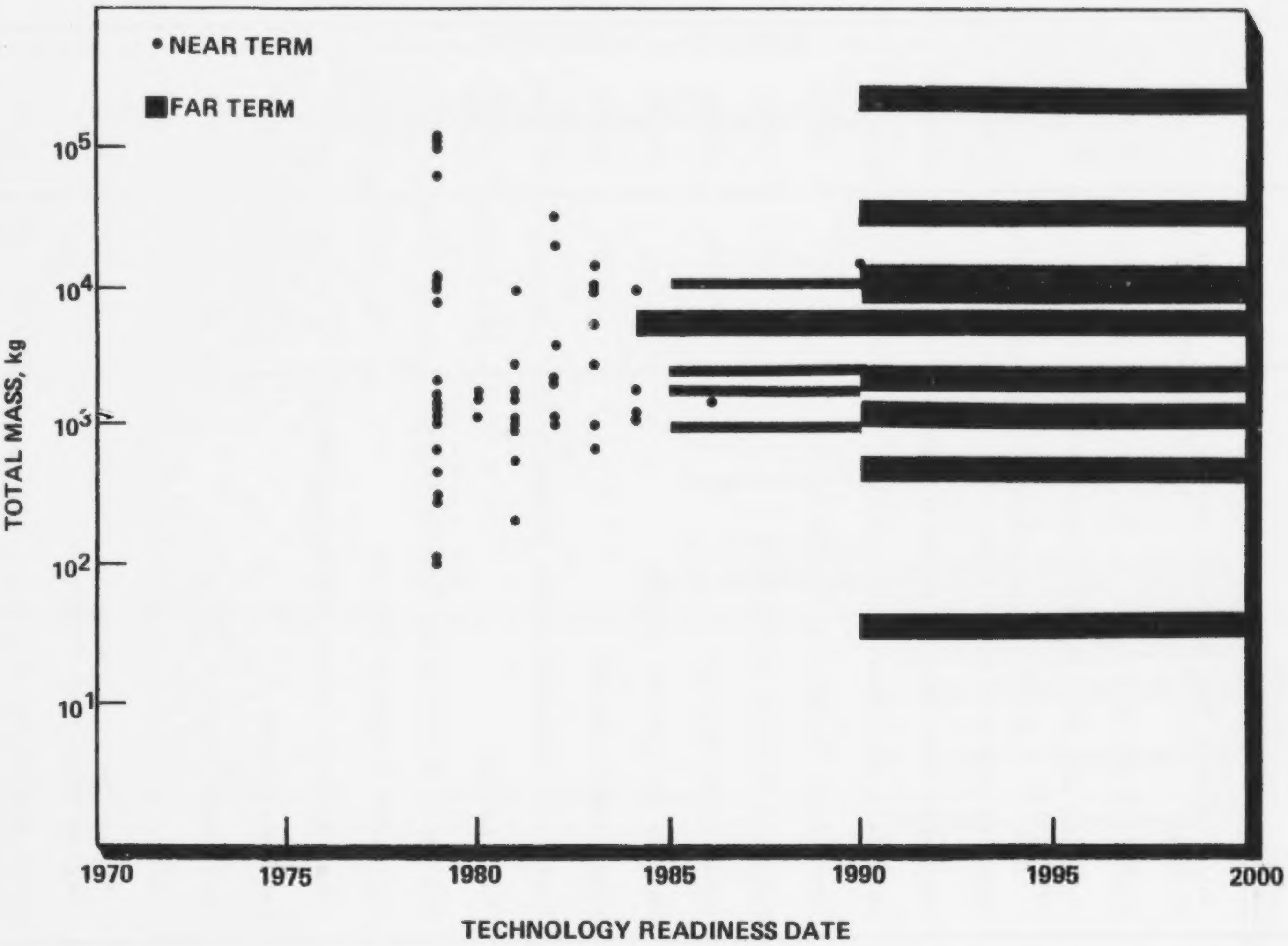
No.	Mission	Value or Range	Technology Readiness Date
C-6	Multi-Service Thin Route Narrowband Program	2300	1984
S-14	Pinhole Satellite	9100	>1984
C-7	Tracking and Data Relay Satellite (TDRSS-II)		1986
T-14	Advanced Electric Propulsion		1990
T-15	Unconventional Orbital Transfer Vehicle		1990
U-12	Materials Experimentation Module		1990
U-13	Space Power Technology Demonstration		1990
P-7	Asteroid Multiple Rendezvous	2000	>1990
P-8	Lunar Polar Orbiter	510	>1990
P-9	Mercury Orbiter and Lander	300-800	>1990
P-10	Comet Sample Return	3000-5000	>1990
P-11	Near Earth Asteroid Sample Return	3000-5000	>1990
P-12	Venus Lander	550	>1990
P-13	Automated Mobile Lunar Surface Survey	250-750	>1990
P-14	Automated Planetary Station	23,000	>1990
P-15	Lunar Backside Lander and Sample Return		>1990
P-16	Ganymede Lander	65	>1990
A-18	IR Interferometer	22,500	>1990
A-19	Gravity Wave Interferometer	16,000	>1990
A-20	Coherent Optical System of Modular Imaging Collectors (COSMIC)	67,000	>1990
A-21	Large Optical/UV Telescope, Diffraction Limited	22,800	>1990

MATERIALS

Total Mass (kg)

No.	Mission	Value or Range	Technology Readiness Date
A-22	100-m Thinned Aperture Telescope	85,000	>1990
S-15	Close Solar Orbiter		>1990
C-8	Orbiting Deep Space Relay Station	8500	>1990
L-3	Search for Extraterrestrial Intelligence (SETI)	ND	TBD
T-13	Heavy-Lift Launch Vehicle	Up to 4.5×10^5	TBD
U-14	Space Operational Center (SOC)		TBD

TECHNOLOGY REQUIREMENTS SUMMARY



Materials and Structures: Total Mass

STRUCTURES

Physical Size (m)

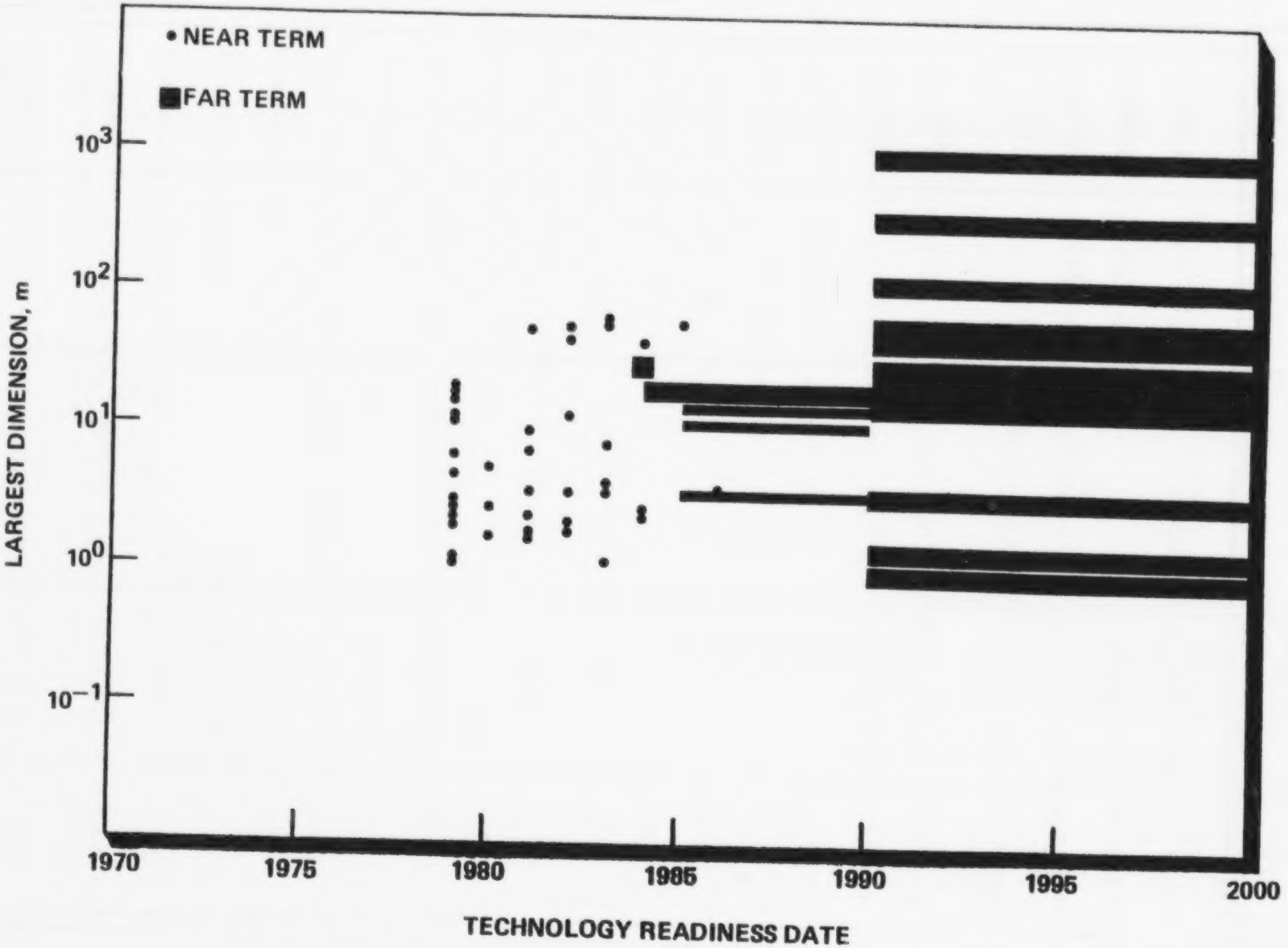
No.	Mission	Value or Range	Technology Readiness Date
C-6	Multi-Service Thin Route Narrowband Program	14-50	1984
S-14	Pinhole Satellite	37×24×25	>1984
C-7	Tracking and Data Relay Satellite (TDRSS-II)		1986
T-14	Advanced Electric Propulsion		1990
T-15	Unconventional Orbital Transfer Vehicle		1990
U-12	Materials Experimentation Module	6×4.6	1990
U-13	Space Power Technology Demonstration	>100	1990
P-7	Asteroid Multiple Rendezvous	35×5×5	>1990
P-8	Lunar Polar Orbiter	4×6×4	>1990
P-9	Mercury Orbiter and Lander	ND	>1990
P-10	Comet Sample Return	70×5×5	>1990
P-11	Near Earth Asteroid Sample Return	70×5×5	>1990
P-12	Venus Lander	2×1.1 dia	>1990
P-13	Automated Mobile Lunar Surface Survey	1.5×0.8×1.0	>1990
P-14	Automated Planetary Station	80×15×9	>1990
P-15	Lunar Backside Lander and Sample Return		>1990
P-16	Ganymede Lander	1 dia	>1990
A-18	IR Interferometer	100×15×9	>1990
A-19	Gravity Wave Interferometer	1000	>1990
A-20	Coherent Optical System of Modular Imaging Collectors (COSMIC)	12×4 dia	>1990
A-21	Large Optical/UV Telescope, Diffraction Limited	28.5×8.4 dia	>1990

STRUCTURES

Physical Size (m)

No.	Mission	Value or Range	Technology Readiness Date
A-22	100-m Thinned Aperture Telescope	100 dia	>1990
S-15	Close Solar Orbiter		>1990
C-8	Orbiting Deep Space Relay Station	28	>1990
L-3	Search for Extraterrestrial Intelligence (SETI)	600 dia	TBD
T-13	Heavy-Lift Launch Vehicle	53	TBD
U-14	Space Operational Center (SOC)		TBD

TECHNOLOGY REQUIREMENTS SUMMARY



Structures: Physical Size

LIFE

Flight Duration (years)

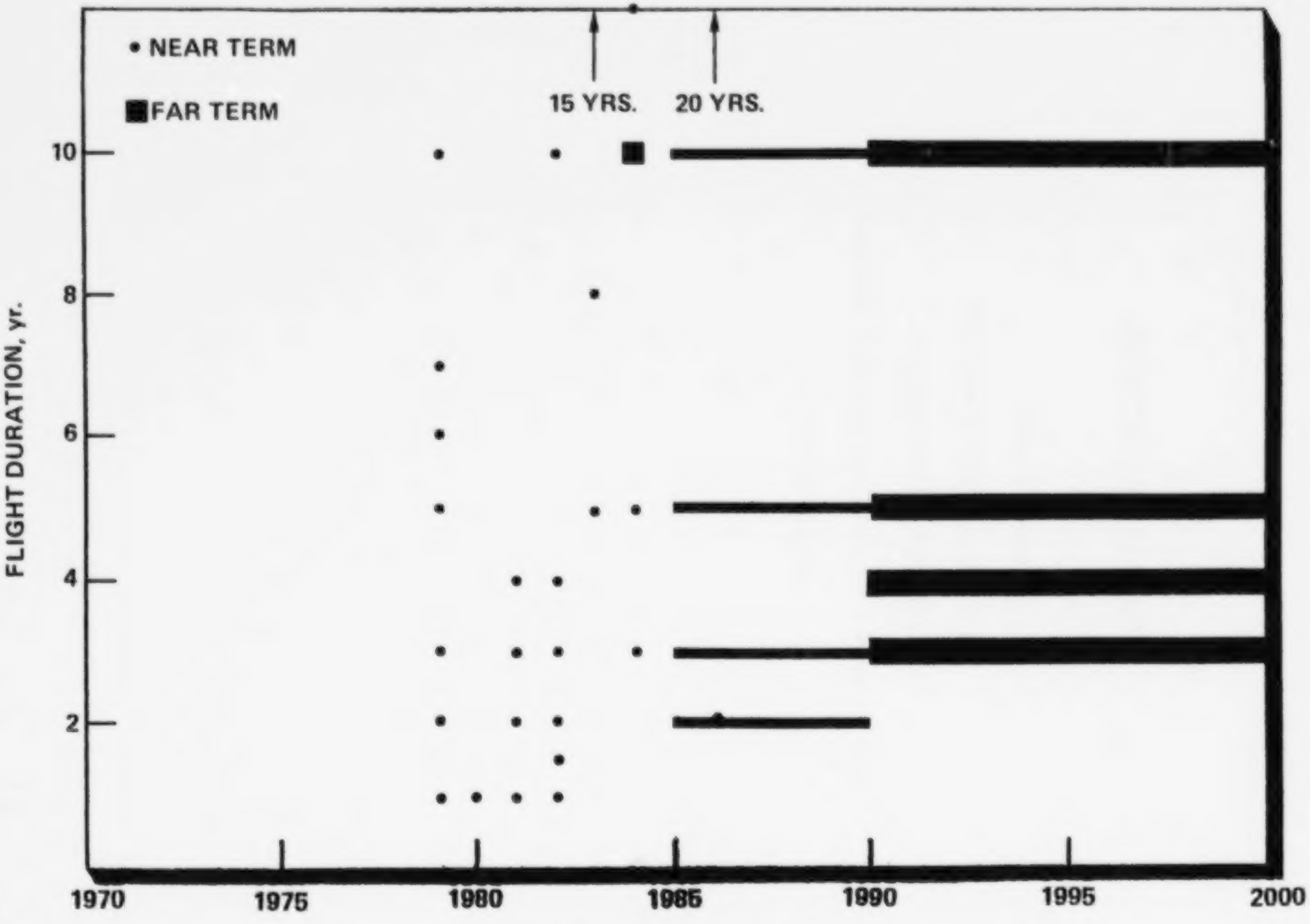
No.	Mission	Value or Range	Technology Readiness Date
C-6	Multi-Service Thin Route Narrowband Program	7-10	1984
S-14	Pinhole Satellite	7 days	>1984
C-7	Tracking and Data Relay Satellite (TDRSS-II)		1986
T-14	Advanced Electric Propulsion	<1 yr or>1 yr	1990
T-15	Unconventional Orbital Transfer Vehicle		1990
U-12	Materials Experimentation Module		1990
U-13	Space Power Technology Demonstration		1990
P-7	Asteroid Multiple Rendezvous	6-10	>1990
P-8	Lunar Polar Orbiter	1.0	>1990
P-9	Mercury Orbiter and Lander	1.5-3.0	>1990
P-10	Comet Sample Return	6	>1990
P-11	Near Earth Asteroid Sample Return	3-4	>1990
P-12	Venus Lander	0.5	>1990
P-13	Automated Mobile Lunar Surface Survey	0.5-3.0	>1990
P-14	Automated Planetary Station	5-10	>1990
P-15	Lunar Backside Lander and Sample Return		>1990
P-16	Ganymede Lander	ND	>1990
A-18	IR Interferometer	5	>1990
A-19	Gravity Wave Interferometer	1-5	>1990
A-20	Coherent Optical System of Modular Imaging Collectors (COSMIC)	10	>1990
A-21	Large Optical/UV Telescope, Diffraction Limited	10	>1990

LIFE

Flight Duration (years)

No.	Mission	Value or Range	Technology Readiness Date
A-22	100-m Thinned Aperture Telescope	10	>1990
S-15	Close Solar Orbiter		>1990
C-8	Orbiting Deep Space Relay Station	10	>1990
L-3	Search for Extraterrestrial Intelligence (SETI)	10	TBD
T-13	Heavy-Lift Launch Vehicle		TBD
U-14	Space Operational Center (SOC)	0.5	TBD

TECHNOLOGY REQUIREMENTS SUMMARY



Life: Flight Duration

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INFORMATION SYSTEMS

Data Volume

On-Board Storage Capacity

Storage Device I/O Rate

Spacecraft Processors/Computers Memory Size

Link Data Rate

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DATA PROCESSING

Data Volume (bits/day)

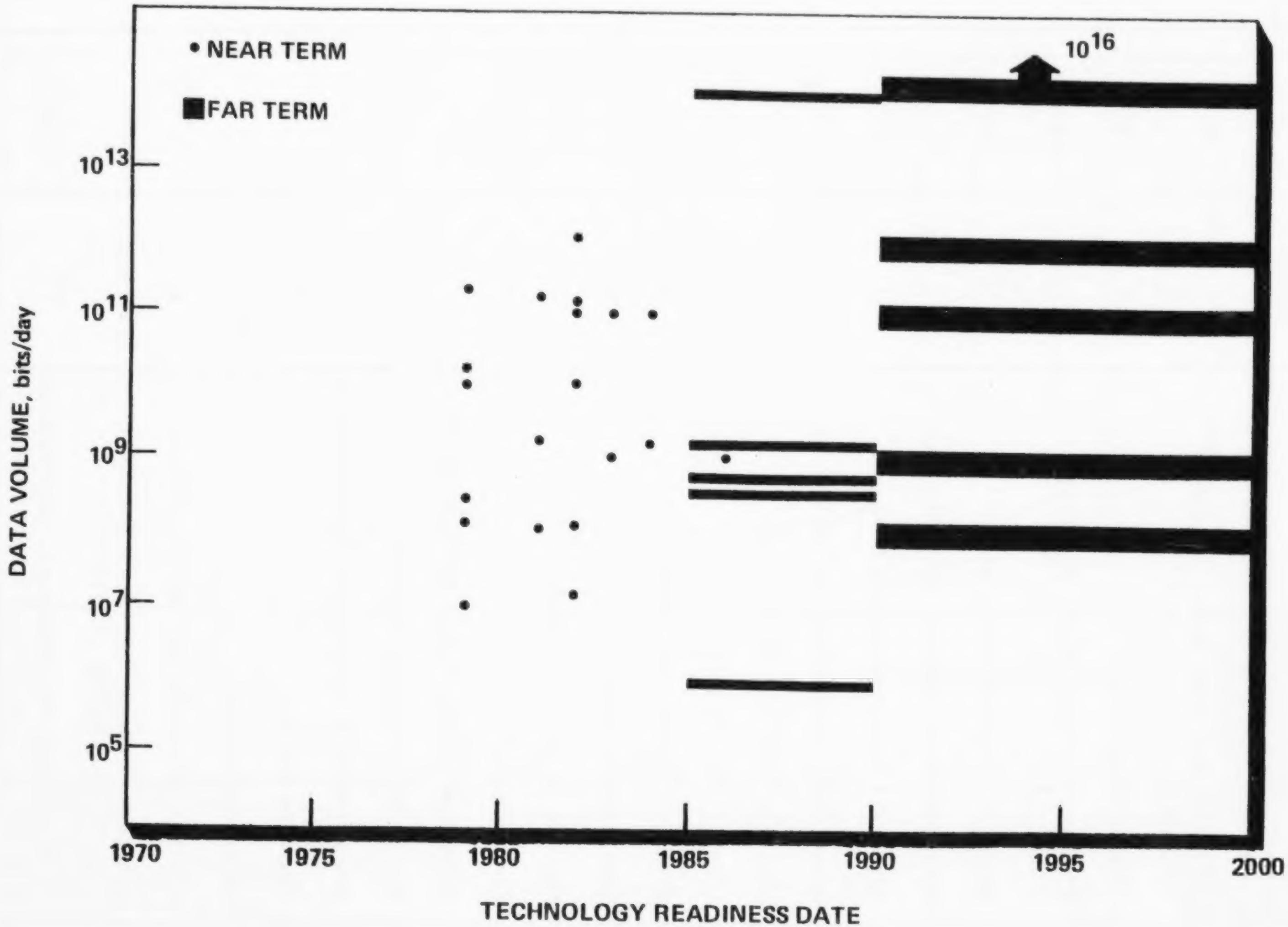
No.	Mission	Value or Range	Technology Readiness Date
C-6	Multi-Service Thin Route Narrowband Program		1984
S-14	Pinhole Satellite	ND	>1984
C-7	Tracking and Data Relay Satellite (TDRSS-II)		1986
T-14	Advanced Electric Propulsion		1990
T-15	Unconventional Orbital Transfer Vehicle		1990
U-12	Materials Experimentation Module		1990
U-13	Space Power Technology Demonstration		1990
P-7	Asteroid Multiple Rendezvous	10^9	>1990
P-8	Lunar Polar Orbiter	10^8-10^9	>1990
P-9	Mercury Orbiter and Lander	10^8-10^9	>1990
P-10	Comet Sample Return	ND	>1990
P-11	Near Earth Asteroid Sample Return	ND	>1990
P-12	Venus Lander	2×10^8	>1990
P-13	Automated Mobile Lunar Surface Survey	10^9	>1990
P-14	Automated Planetary Station	10^{11}	>1990
P-15	Lunar Backside Lander and Sample Return		>1990
P-16	Ganymede Lander	ND	>1990
A-18	IR Interferometer	10^{10}-10^{12}	>1990
A-19	Gravity Wave Interferometer	ND	>1990
A-20	Coherent Optical System of Modular Imaging Collectors (COSMIC)	10^{10}-10^{12}	>1990
A-21	Large Optical/UV Telescope, Diffraction Limited	ND	>1990

DATA PROCESSING

Data Volume (bits/day)

No.	Mission	Value or Range	Technology Readiness Date
A-22	100-m Thinned Aperture Telescope	10^{10}-10^{12}	>1990
S-15	Close Solar Orbiter		>1990
C-8	Orbiting Deep Space Relay Station		>1990
L-3	Search for Extraterrestrial Intelligence (SETI)	$\leq 10^{16}$	TBD
T-13	Heavy-Lift Launch Vehicle		TBD
U-14	Space Operational Center (SOC)		TBD

TECHNOLOGY REQUIREMENTS SUMMARY



Data Processing: Data Volume

DATA PROCESSING

On-Board Storage Capacity (bits)

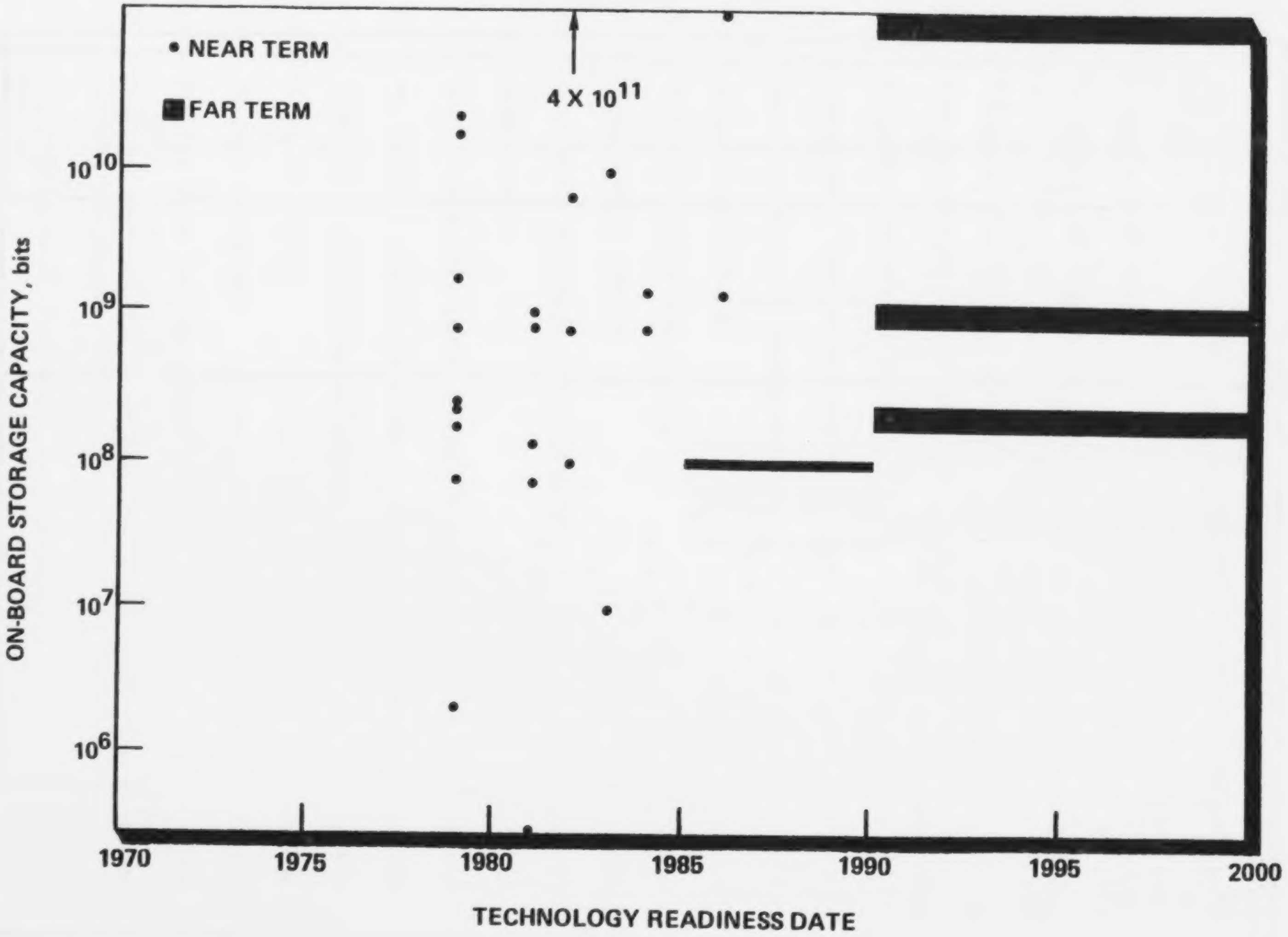
No.	Mission	Value or Range	Technology Readiness Date
C-6	Multi-Service Thin Route Narrowband Program		1984
S-14	Pinhole Satellite	ND	>1984
C-7	Tracking and Data Relay Satellite (TDRSS-II)		1986
T-14	Advanced Electric Propulsion		1990
T-15	Unconventional Orbital Transfer Vehicle		1990
U-12	Materials Experimentation Module		1990
U-13	Space Power Technology Demonstration		1990
P-7	Asteroid Multiple Rendezvous	2×10^9	>1990
P-8	Lunar Polar Orbiter	4×10^8	>1990
P-9	Mercury Orbiter and Lander	ND	>1990
P-10	Comet Sample Return	ND	>1990
P-11	Near Earth Asteroid Sample Return	ND	>1990
P-12	Venus Lander	ND	>1990
P-13	Automated Mobile Lunar Surface Survey	10^9	>1990
P-14	Automated Planetary Station	ND	>1990
P-15	Lunar Backside Lander and Sample Return		>1990
P-16	Ganymede Lander	ND	>1990
A-18	IR Interferometer	10^{10}-10^{11}	>1990
A-19	Gravity Wave Interferometer	ND	>1990
A-20	Coherent Optical System of Modular Imaging Collectors (COSMIC)	10^{10}-10^{11}	>1990
A-21	Large Optical/UV Telescope, Diffraction Limited	ND	>1990

DATA PROCESSING

On-Board Storage Capacity (bits)

No.	Mission	Value or Range	Technology Readiness Date
A-22	100-m Thinned Aperture Telescope	10^{10}-10^{11}	>1990
S-15	Close Solar Orbiter		>1990
C-8	Orbiting Deep Space Relay Station		>1990
L-3	Search for Extraterrestrial Intelligence (SETI)	NA	TBD
T-13	Heavy-Lift Launch Vehicle		TBD
U-14	Space Operational Center (SOC)		TBD

TECHNOLOGY REQUIREMENTS SUMMARY



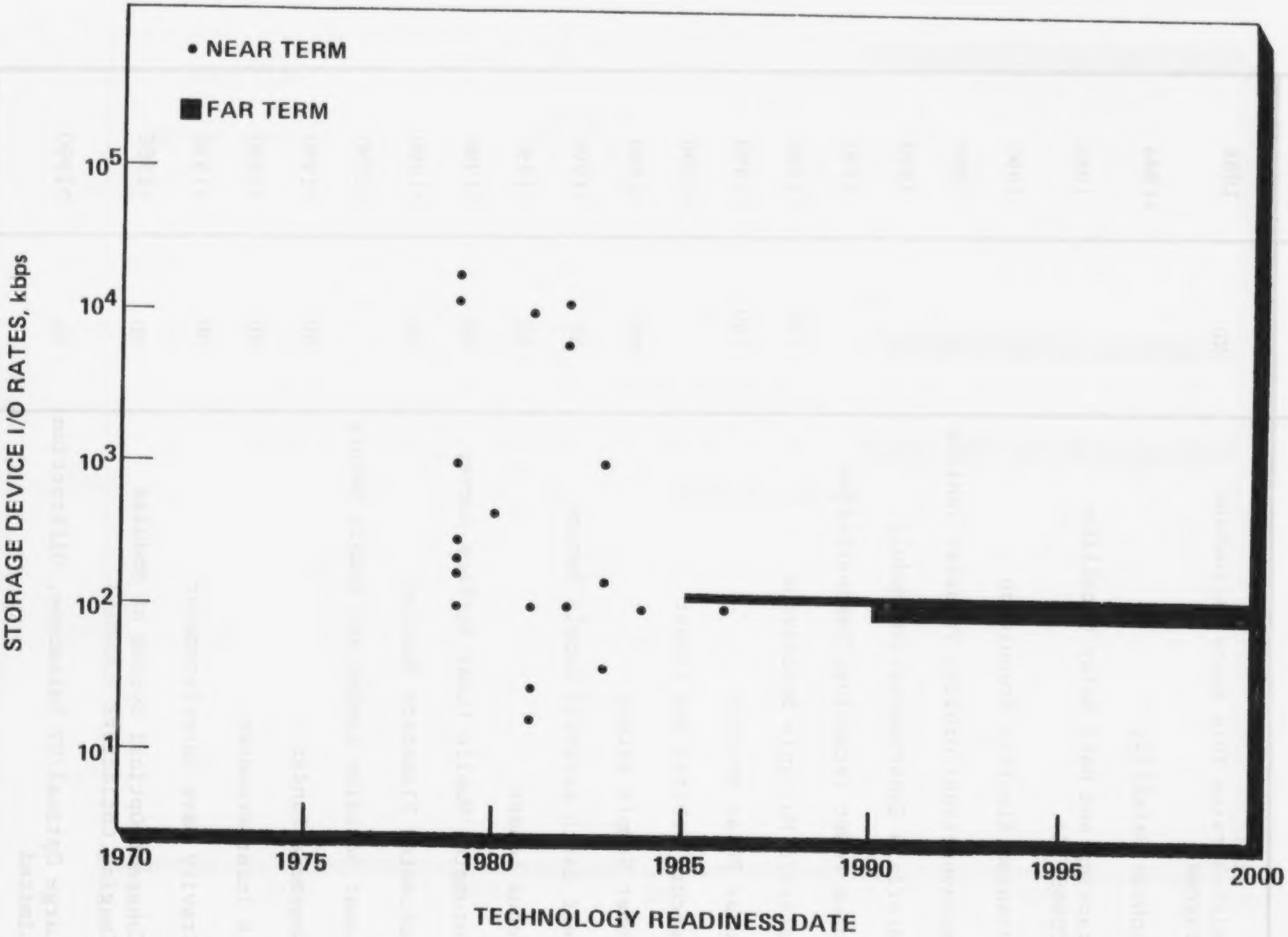
Data Processing: On-Board Storage Capacity

DATA PROCESSING

Storage Device I/O Rates (kbps)

No.	Mission	Value or Range	Technology Readiness Date
C-6	Multi-Service Thin Route Narrowband Program	ND	1984
S-14	Pinhole Satellite		>1984
C-7	Tracking and Data Relay Satellite (TDRSS-II)		1986
T-14	Advanced Electric Propulsion		1990
T-15	Unconventional Orbital Transfer Vehicle		1990
U-12	Materials Experimentation Module		1990
U-13	Space Power Technology Demonstration		1990
P-7	Asteroid Multiple Rendezvous	120	>1990
P-8	Lunar Polar Orbiter	180	>1990
P-9	Mercury Orbiter and Lander		>1990
P-10	Comet Sample Return	ND	>1990
P-11	Near Earth Asteroid Sample Return	ND	>1990
P-12	Venus Lander	ND	>1990
P-13	Automated Mobile Lunar Surface Survey	ND	>1990
P-14	Automated Planetary Station	ND	>1990
P-15	Lunar Backside Lander and Sample Return		>1990
P-16	Ganymede Lander	ND	>1990
A-18	IR Interferometer	ND	>1990
A-19	Gravity Wave Interferometer	ND	>1990
A-20	Coherent Optical System of Modular Imaging Collectors (COSMIC)	ND	>1990
A-21	Large Optical/UV Telescope, Diffraction Limited	ND	>1990

TECHNOLOGY REQUIREMENTS SUMMARY



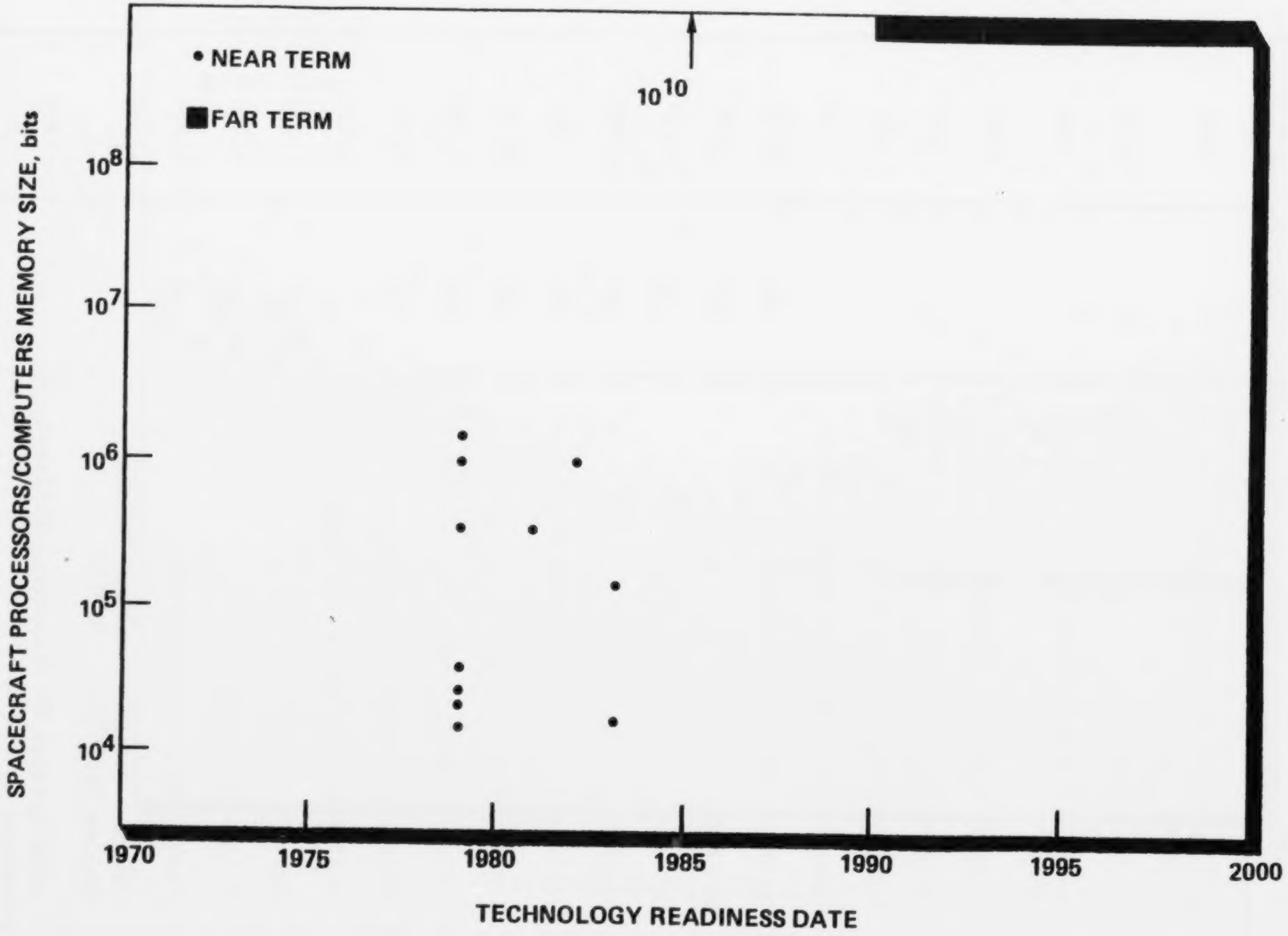
Data Processing: Storage Device I/O Rate

DATA PROCESSING

Spacecraft Processors/Computers Memory Size (bits)

No.	Mission	Value or Range	Technology Readiness Date
C-6	Multi-Service Thin Route Narrowband Program		1984
S-14	Pinhole Satellite		>1984
C-7	Tracking and Data Relay Satellite (TDRSS-II)		1986
T-14	Advanced Electric Propulsion		1990
T-15	Unconventional Orbital Transfer Vehicle		1990
U-12	Materials Experimentation Module		1990
U-13	Space Power Technology Demonstration		1990
P-7	Asteroid Multiple Rendezvous	ND	>1990
P-8	Lunar Polar Orbiter	ND	>1990
P-9	Mercury Orbiter and Lander	ND	>1990
P-10	Comet Sample Return	ND	>1990
P-11	Near Earth Asteroid Sample Return	ND	>1990
P-12	Venus Lander	ND	>1990
P-13	Automated Mobile Lunar Surface Survey	ND	>1990
P-14	Automated Planetary Station	10^9	>1990
P-15	Lunar Backside Lander and Sample Return		>1990
P-16	Ganymede Lander	ND	>1990
A-18	IR Interferometer	ND	>1990
A-19	Gravity Wave Interferometer	ND	>1990
A-20	Coherent Optical System of Modular Imaging Collectors (COSMIC)	ND	>1990
A-21	Large Optical/UV Telescope, Diffraction Limited	ND	>1990

TECHNOLOGY REQUIREMENTS SUMMARY



Data Processing: Spacecraft Processors/ Computers Memory Size

COMMUNICATIONS

Link Data Rate (kbps)

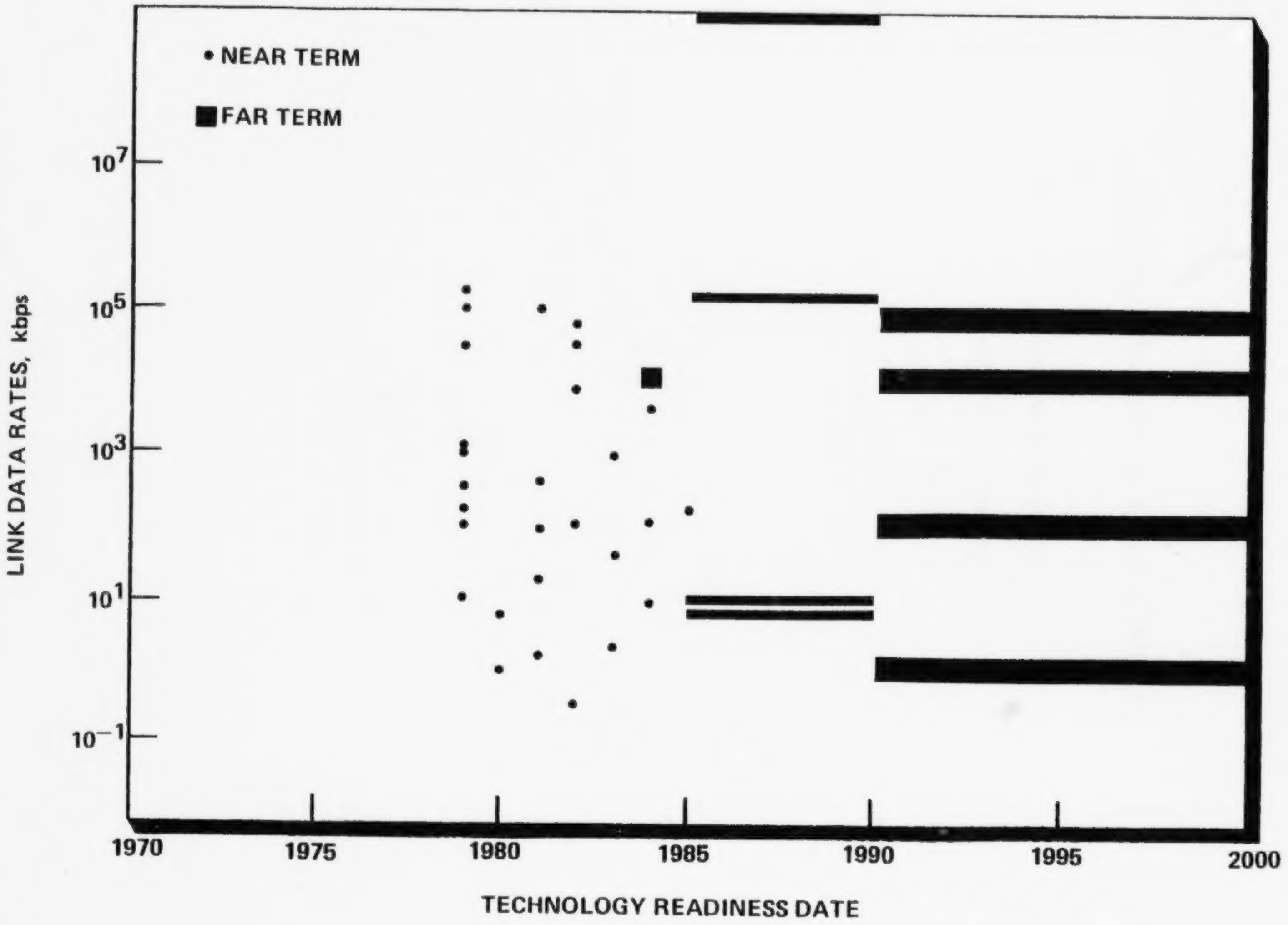
No.	Mission	Value or Range	Technology Readiness Date
C-6	Multi-Service Thin Route Narrowband Program	10^4	1984
S-14	Pinhole Satellite	ND	>1984
C-7	Tracking and Data Relay Satellite (TDRSS-II)		1986
T-14	Advanced Electric Propulsion		1990
T-15	Unconventional Orbital Transfer Vehicle		1990
U-12	Materials Experimentation Module		1990
U-13	Space Power Technology Demonstration		1990
P-7	Asteroid Multiple Rendezvous	0.2-120 (DL); ND (UL)	>1990
P-8	Lunar Polar Orbiter	4-180; 0.25 (DL) (UL)	>1990
P-9	Mercury Orbiter and Lander	1-120; ND (DL) (UL)	>1990
P-10	Comet Sample Return	ND; ND (DL) (UL)	>1990
P-11	Near Earth Asteroid Sample Return	ND; ND (DL) (UL)	>1990
P-12	Venus Lander	2; ND (DL) (UL)	>1990
P-13	Automated Mobile Lunar Surface Survey	ND; ND (DL) (UL)	>1990
P-14	Automated Planetary Station	10^5; ND (DL) (UL)	>1990
P-15	Lunar Backside Lander and Sample Return		>1990
P-16	Ganymede Lander	ND; ND (DL) (UL)	>1990
A-18	IR Interferometer	10^2-10^5 (DL)	>1990
A-19	Gravity Wave Interferometer	ND (DL)	>1990
A-20	Coherent Optical System of Modular Imaging Collectors (COSMIC)	10^2-10^5 (DL)	>1990
A-21	Large Optical/UV Telescope, Diffraction Limited	ND (DL)	>1990

COMMUNICATIONS

Link Data Rate (kbps)

No.	Mission	Value or Range	Technology Readiness Date
A-22	100-m Thinned Aperture Telescope	10^2-10^5 (DL)	>1990
S-15	Close Solar Orbiter		>1990
C-8	Orbiting Deep Space Relay Station	25-2.5×10^4	>1990
L-3	Search for Extraterrestrial Intelligence (SETI)		TBD
T-13	Heavy-Lift Launch Vehicle		TBD
U-14	Space Operational Center (SOC)		TBD

TECHNOLOGY REQUIREMENTS SUMMARY



Communications: Link Data Rate

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NAVIGATION, GUIDANCE AND CONTROL

Pointing Accuracy

Position Accuracy

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NAVIGATION AND ATTITUDE CONTROL

Pointing Accuracy (mrad)

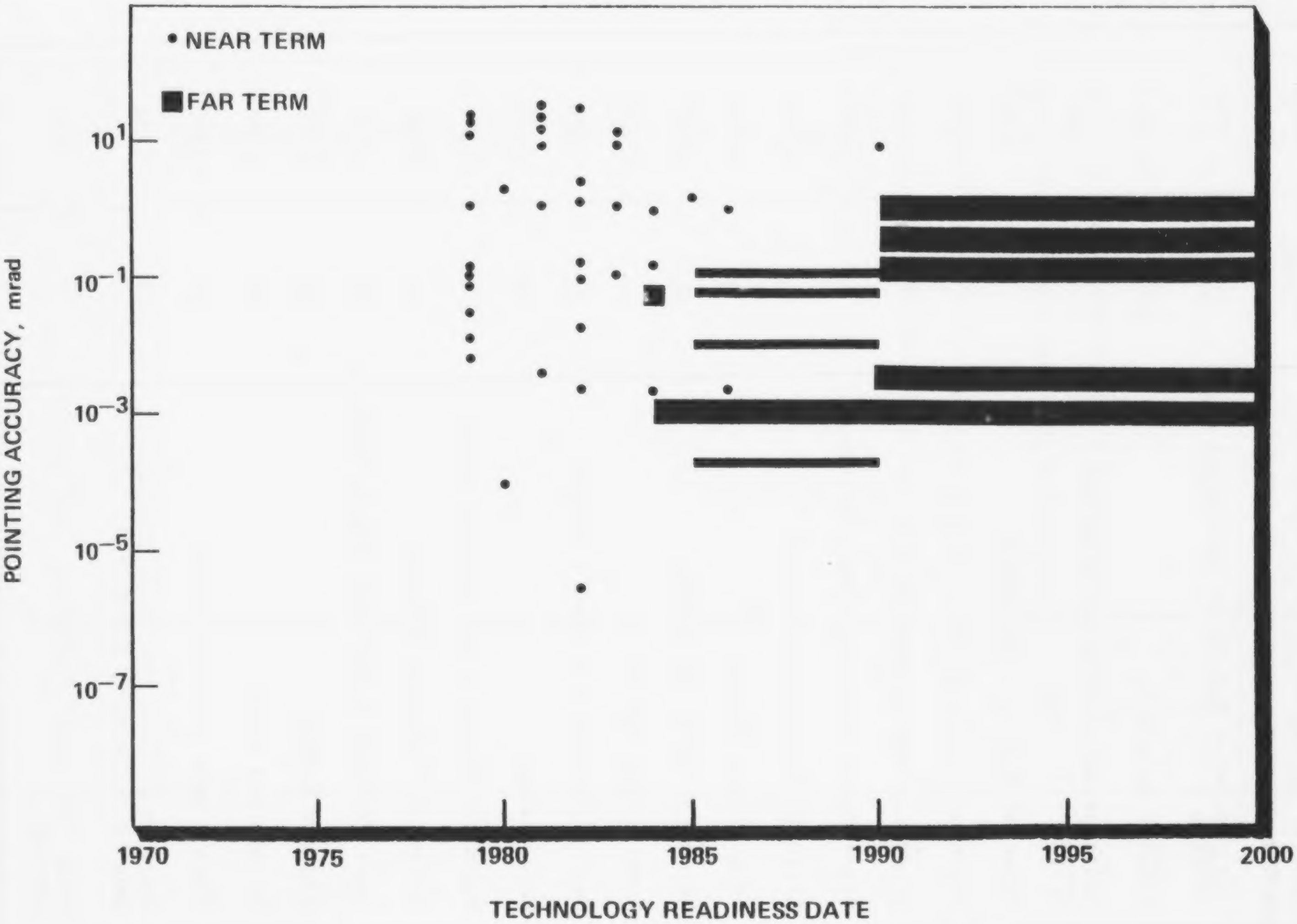
No.	Mission	Value or Range	Technology Readiness Date
C-6	Multi-Service Thin Route Narrowband Program	0.08	1984
S-14	Pinhole Satellite	0.002	>1984
C-7	Tracking and Data Relay Satellite (TDRSS-II)		1986
T-14	Advanced Electric Propulsion		1990
T-15	Unconventional Orbital Transfer Vehicle		1990
U-12	Materials Experimentation Module		1990
U-13	Space Power Technology Demonstration		1990
P-7	Asteroid Multiple Rendezvous	ND	>1990
P-8	Lunar Polar Orbiter	1.0	>1990
P-9	Mercury Orbiter and Lander	ND	>1990
P-10	Comet Sample Return	ND	>1990
P-11	Near Earth Asteroid Sample Return	ND	>1990
P-12	Venus Lander	NA	>1990
P-13	Automated Mobile Lunar Surface Survey	ND	>1990
P-14	Automated Planetary Station	ND	>1990
P-15	Lunar Backside Lander and Sample Return	ND	>1990
P-16	Ganymede Lander	ND	>1990
A-18	IR Interferometer	ND	>1990
A-19	Gravity Wave Interferometer	ND	>1990
A-20	Coherent Optical System of Modular Imaging Collectors (COSMIC)	ND	>1990
A-21	Large Optical/UV Telescope, Diffraction Limited	0.005	>1990

NAVIGATION AND ATTITUDE CONTROL

Pointing Accuracy (mrad)

No.	Mission	Value or Range	Technology Readiness Date
A-22	100-m Thinned Aperture Telescope	ND	>1990
S-15	Close Solar Orbiter	ND	>1990
C-8	Orbiting Deep Space Relay Station	0.35	>1990
L-3	Search for Extraterrestrial Intelligence (SETI)	0.5	TBD
T-13	Heavy-Lift Launch Vehicle		TBD
U-14	Space Operational Center (SOC)		TBD

TECHNOLOGY REQUIREMENTS SUMMARY



Navigation and Attitude Control: Pointing Accuracy

GUIDANCE AND CONTROL

Position Accuracy (km)

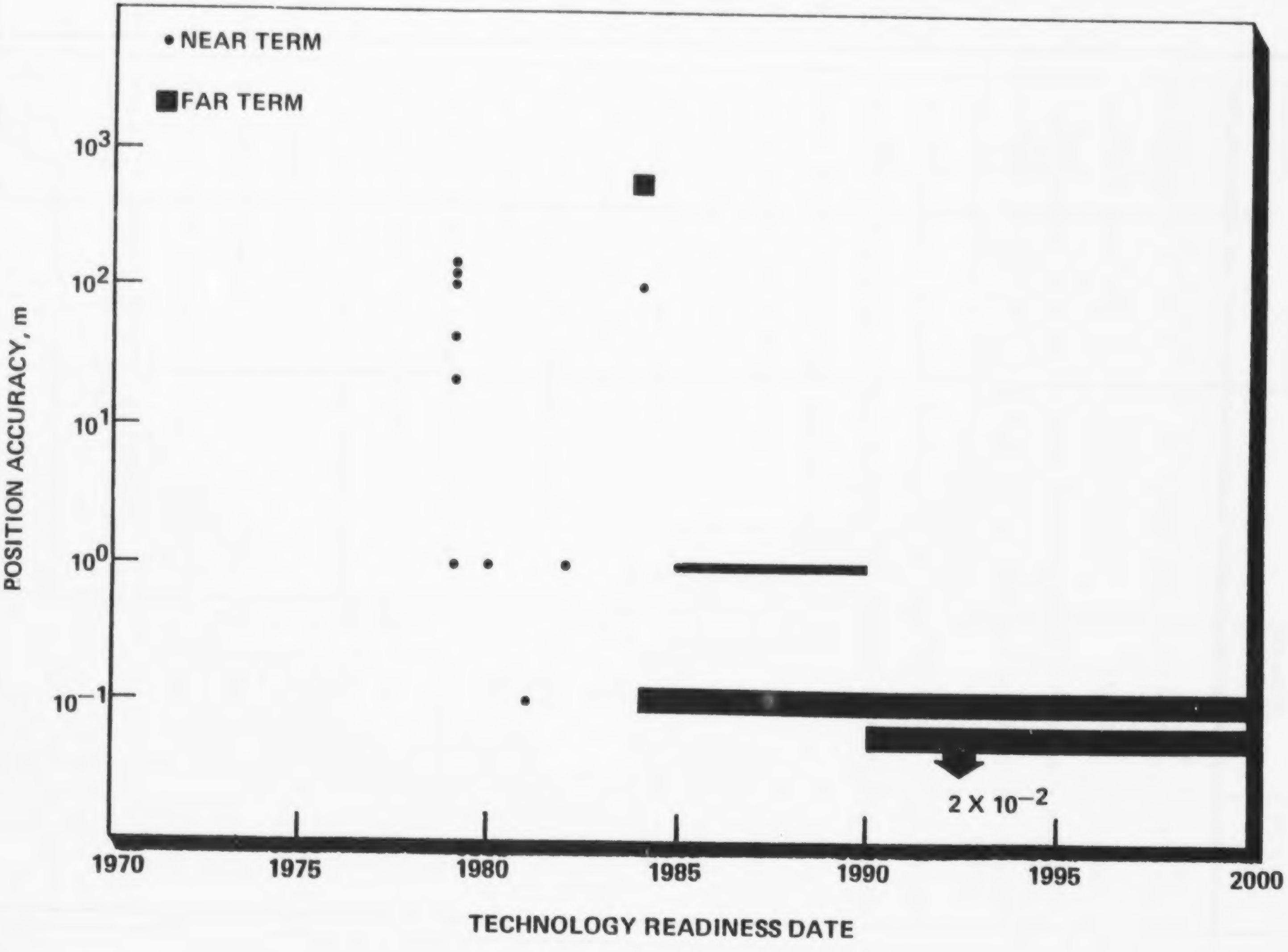
No.	Mission	Value or Range	Technology Readiness Date
C-6	Multi-Service Thin Route Narrowband Program	0.8	1984
S-14	Pinhole Satellite	10^{-4}	>1984
C-7	Tracking and Data Relay Satellite (TDRSS-II)		1986
T-14	Advanced Electric Propulsion		1990
T-15	Unconventional Orbital Transfer Vehicle		1990
U-12	Materials Experimentation Module		1990
U-13	Space Power Technology Demonstration		1990
P-7	Asteroid Multiple Rendezvous	ND	>1990
P-8	Lunar Polar Orbiter	ND	>1990
P-9	Mercury Orbiter and Lander	ND	>1990
P-10	Comet Sample Return	ND	>1990
P-11	Near Earth Asteroid Sample Return	ND	>1990
P-12	Venus Lander	ND	>1990
P-13	Automated Mobile Lunar Surface Survey	$\sim 2 \times 10^{-5}$	>1990
P-14	Automated Planetary Station	ND	>1990
P-15	Lunar Backside Lander and Sample Return	ND	>1990
P-16	Ganymede Lander	ND	>1990
A-18	IR Interferometer	NA	>1990
A-19	Gravity Wave Interferometer	NA	>1990
A-20	Coherent Optical System of Modular Imaging Collectors (COSMIC)	NA	>1990
A-21	Large Optical/UV Telescope, Diffraction Limited	ND	>1990

GUIDANCE AND CONTROL

Position Accuracy (km)

No.	Mission	Value or Range	Technology Readiness Date
A-22	100-m Thinned Aperture Telescope	NA	>1990
S-15	Close Solar Orbiter	ND	>1990
C-8	Orbiting Deep Space Relay Station	10^{-4}	>1990
L-3	Search for Extraterrestrial Intelligence (SETI)	ND	TBD
T-13	Heavy-Lift Launch Vehicle		TBD
U-14	Space Operational Center (SOC)		TBD

TECHNOLOGY REQUIREMENTS SUMMARY



Guidance and Control: Position Accuracy

ACKNOWLEDGEMENT

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PART B: OPPORTUNITY MISSIONS FROM OTHER SOURCES

1 INTRODUCTION

This volume presents "missions" which are not "validated by the NASA program offices. "Validated" means an office is willing to endorse a mission as a long-range technology driver by having it appear in the office's section(s) of the Model. Program offices might be constrained by budget perceptions, need to express reasonable priorities, and need to avoid official association with very speculative or controversial missions. In any case, the program offices are, in effect, not endorsing the technology development implied by most of the missions in this part.

Early in the development of the Model, NASA realized that the validated missions presented in Volume I and Volume III, Part A would be inadequate for driving long-range technology. Volume III, Part B was created to expand the set of opportunity missions so that an adequate "landmark" mission set could be selected for technology planning purposes.

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2 SUMMARY

Table 1 presents a ranking of 134 imaginative missions gathered from various sources. The ranking resulted from a voting process by individuals selected by the Associate Administrators of NASA Headquarters. Table 2 presents the descriptions seen by the voters of the top thirty missions.

This ranking does not represent an official NASA prioritization. It is offered as a best-available ordering. It may be useful as a guide for selecting long-range missions and technology for definition and development.

Appendixes which follow detail the process by which this ranking was produced.

TABLE 1

REPRESENTATIVE RANKING OF IMAGINATIVE MISSIONS

This table presents the mission ranking selected as most representative of the consensus of the voters.

TABLE 1

These are the definitions of column headings on the printout of mission ranking.

MISSION TITLE:	A short descriptive name.
ID:	An identifier left over from the original selection of missions from the sources (see Appendix C).
NO. LNS:	The number of lines in a mission description on the ballot. Useful for detecting connection between rank and quantity of description.
NO. OF RESPONSES:	The number of outstanding (*), interesting (+), no opinion (o), blank (B), or negative (-) responses received for that mission.
TOTAL SCORE:	The sum of the score using the weights presented at the bottom of the printouts.
NUM RESP:	Number of voters who gave an opinionated vote on the mission (*, +, or -).
MEAN SCORE:	The total score divided by the number of opinionated votes received for that mission.
STD DEV:	Standard deviation of the opinionated vote scores.
VARIANCE:	Standard deviation squared.
RATIO:	Total score divided by standard deviation.

04/30/80 OAST MISSION OPPORTUNITY RESPONSE ANALYSIS RANKING SCHEDULE PAGE 1

RANKING BY MEAN SCORE

	MISSION TITLE	ID	NO. LNS	NO. OF RESPONSES *	+	0	B	-	TOTAL SCORE	NUM RESP	MEAN SCORE	STD DEV	VARIANCE	RATIO
1	PERMANENT ORBITING OUTPOST	A9	5	18	10	3	8	1	45	29	1.552	0.686	0.470	065.598
2	LANDSAT H.(10-M RES ACTIVE/PASSIVE OBSERVATIONS)	E1	7	7	14	9	10	0	28	21	1.333	0.483	0.233	057.971
3	GEOSYNCHRONOUS TELEPHONE SWITCHING UTILITY	A13	6	10	15	5	9	1	34	26	1.308	0.680	0.462	050.000
4	GEOSYNCHRONOUS BROADBAND COMPUTER LINKS	A15	8	8	19	4	9	0	35	27	1.296	0.466	0.217	075.107
5	INTERNATIONAL HALLEY COMET WATCH	A31	4	13	9	6	9	3	32	25	1.280	0.980	0.960	032.653
6	OCEAN EXPLORING SYSTEM	A23	11	9	16	3	11	1	33	26	1.269	0.667	0.445	049.475
7	GLOBAL SEARCH AND RESCUE LOCATOR	B15	4	6	21	4	9	0	33	27	1.222	0.423	0.179	078.014
8	ORBITING CIVIL COMMAND AND CONTROL STATION	A16	4	8	10	11	9	2	24	20	1.200	0.894	0.800	026.846
9	NUCLEAR WASTE DISPOSAL	A2	15	13	10	5	8	4	32	27	1.185	1.039	1.080	030.799
10	HIGHLY AUTONOMOUS TELE-ROBOT	A12	5	10	14	5	8	3	31	27	1.148	0.907	0.823	034.179
11	MULTIPLANET FLYBYS AND GRAVITY ASSIST	D40	3	3	18	8	11	0	24	21	1.143	0.359	0.129	066.852
12	WATER LEVEL AND FAULT MOVEMENT INDICATOR	B3	4	5	16	7	11	1	25	22	1.136	0.640	0.409	039.063
13	SPACE-BASED ATMOSPHERIC RESEARCH FACILITY	A6	2	7	14	6	11	2	26	23	1.130	0.815	0.664	031.902
14	CLOSE SOLAR ORBITER	D47	3	4	12	13	10	1	19	17	1.118	0.696	0.485	027.299
15	HIGH RESOLUTION EARTH MAPPING RADAR	B13	3	4	18	7	10	1	25	23	1.087	0.597	0.356	041.876
16	10-M OPTICAL INTERFEROMETER	A17	18	5	7	19	7	2	15	14	1.071	0.997	0.995	015.045
17	EVOLUTION OF PLANETARY EXPLORTATION GOALS	A34	3	7	12	7	11	3	23	22	1.045	0.950	0.903	024.211
18	SPACE-BASED ASTROPHYSICS RESEARCH FACILITY	A5	5	7	19	4	7	3	30	29	1.034	0.823	0.677	036.452
19	SURFACE ROVERS	D49	4	6	13	8	10	3	22	22	1.000	0.926	0.857	023.758
20	TRANSPORTATION SERVICES SATELLITES	B19	6	5	16	7	9	3	23	24	0.958	0.858	0.737	026.807
21	AUTOMATED PLANETARY STATION	A3	18	8	14	3	10	5	25	27	0.926	1.035	1.071	024.155
22	SYNCHRONOUS METEOROLOGICAL SATELLITE	B12	4	2	10	15	11	2	12	14	0.857	0.864	0.747	013.889
23	SPACE-BASED HEALTH CARE RESEARCH FACILITY	A7	21	6	14	6	9	5	21	25	0.840	1.028	1.057	020.428
24	DETECTION OF OTHER PLANETARY SYSTEMS	D9	1	3	11	14	9	3	14	17	0.824	0.951	0.904	014.721
25	SINGLE-STAGE-TO-ORBIT SHUTTLE	D97	3	1	3	2	33	1	4	5	0.800	1.095	1.200	003.653
26	DOPPLER MILLIHERTZ GRAVITY WAVE DETECTION	A21	4	5	5	19	7	4	11	14	0.786	1.251	1.566	008.793
27	PERMANENT LUNAR OUTPOST	A8	18	8	13	3	9	7	22	28	0.786	1.134	1.286	019.400
28	ADVANCED RESOURCES/POLLUTION OBSERVATORY	B1	4	3	15	8	10	4	17	22	0.773	0.922	0.851	018.438
29	COMBINED MISSIONS W/PRIMARY ENG-SCIE OBJECTIVES	D76	3	6	5	13	11	5	12	16	0.750	1.291	1.667	009.295
30	OPER OF SHUTTLE OUT OF AN EQUATORIAL LAUNCH SITE	D18	4	2	3	0	33	2	5	7	0.714	1.253	1.571	003.990
31	ACTIVE ATMOSPHERIC TEMPERATURE PROFILE SOUNDER	B11	4	2	9	15	11	3	10	14	0.714	0.994	0.989	010.060
32	SOLAR POWER SATELLITE	A1A	8	6	15	3	9	7	20	28	0.714	1.084	1.175	018.450
33	EARTHWATCH (CONTINUOUS HIGH RES COVERAGE)	E2	7	4	11	10	10	5	14	20	0.700	1.081	1.168	012.951
34	DISASTER COMMUNICATIONS SET	B17	2	4	16	5	9	6	18	26	0.692	1.011	1.022	017.804
35	DIPLOMATIC/UN HOTLINES	B24	3	2	18	5	10	5	17	25	0.680	0.900	0.810	018.889
36	LASER INTERFEROMETER GRAVITY WAVE DETECTOR	A20	3	0	15	14	8	3	12	18	0.667	0.767	0.588	015.645
37	NON-TERRESTRIAL MATERIALS FOR SPACE USE	A10	9	2	12	14	8	4	12	18	0.667	0.970	0.941	012.371
38	TIME DIFFERENCE COOPERATIVE COLLISION AVOIDANCE	A27	2	2	10	14	10	4	10	16	0.625	1.025	1.050	009.756
39	STANDARDIZED PLANETARY MISSION HARDWARE	A30	3	3	15	6	10	6	15	24	0.625	1.013	1.027	014.808
40	MANNED PLANETARY MISSION (MARS)	A35	8	7	9	6	10	8	15	24	0.625	1.245	1.549	012.048
41	SOLAR PENETRATOR	D46	3	4	10	10	10	6	12	20	0.600	1.142	1.305	010.508
42	JUPITER ATMOSPHERE BALLOON	D2	3	2	12	11	10	5	11	19	0.579	1.017	1.035	010.816
43	LUNAR FARSIDE RADIO TELESCOPE	D6	2	5	13	7	7	8	15	26	0.577	1.138	1.294	013.181
44	COMET "PIGGYBACK" PROBE	D44	3	4	12	7	10	7	13	23	0.565	1.121	1.257	011.597
45	GAMMA RAY COMPTON TELESCOPE AND POLARIMETER	F1	3	3	4	21	8	4	6	11	0.545	1.293	1.673	004.640
46	ICARUS 'PEEK A-BOO' MISSION	D108	3	0	3	3	33	1	2	4	0.500	1.000	1.000	002.000
47	2-D OPTICAL INTERFEROMETER (100 METER DIAMETER)	A18	3	1	12	15	7	5	9	18	0.500	0.985	0.971	009.137

WEIGHTING FACTORS: OUTSTANDING(2),ATTRACTIVE(1),NO OPINION(0), NO RESPONSE(0), UNATTRACTIVE(-1)

TABLE 1 (Cont.)

RANKING BY MEAN SCORE

	MISSION TITLE	ID	NO. LNS	NO. OF RESPONSES *	+	O	B		TOTAL SCORE	NUM RESP	MEAN SCORE	STD DEV	VARIANCE	RATIO
48	VENUS SURFACE STATION	D11	2	1	15	8	10	6	11	22	0.500	0.964	0.929	011.411
49	SEARCH FOR EXTRATERRESTRIAL LIFE	D38	2	4	12	7	9	8	12	24	0.500	1.142	1.304	010.508
50	VENUS BATHYSPHERE	D43	2	2	13	8	10	7	10	22	0.455	1.057	1.117	009.461
51	VERY LARGE ANNULUS OPTICAL TELESCOPE (100-M DIA)	D90	3	1	13	13	7	6	9	20	0.450	0.998	0.997	009.018
52	OZONE LAYER REPLENISHENT/PROTECTION	B38	4	3	7	13	11	6	7	16	0.438	1.210	1.463	005.785
53	SUPER-SYNCHRONOUS JUNKYARD	D86	5	0	5	0	33	2	3	7	0.429	0.976	0.952	003.074
54	URBAN/POLICE WRIST RADIO	B16	3	2	14	7	9	8	10	24	0.417	1.060	1.123	009.434
55	GEOS (EARTH OBSERVATION FROM GEO AT 3-METER RES)	F3	3	1	11	12	10	6	7	18	0.389	1.037	1.075	006.750
56	MICROSAT (1 KM L-BAND RES FOR SOIL MOISTURE	E7	5	0	10	14	11	5	5	15	0.333	0.976	0.952	005.123
57	NUCLEAR FUEL LOCATOR	B7	5	3	7	13	9	8	5	18	0.278	1.228	1.507	004.072
58	THERMAL INERTIA MAPPER	E5	3	1	6	17	11	5	3	12	0.250	1.138	1.295	002.636
59	CONFIRMATION OF BLACK HOLES	D89	5	3	8	13	7	9	5	20	0.250	1.209	1.461	004.136
60	FIRE DETECTION	B2	3	0	13	9	10	8	5	21	0.238	0.995	0.990	005.025
61	DEEP PROBES OF ICY SATELLITES	A33	4	2	8	11	11	8	4	18	0.222	1.166	1.359	003.431
62	CATALOG OF SOLAR SYSTEMS RESOURCES	D71	2	2	8	11	11	8	4	18	0.222	1.166	1.359	003.431
63	PERSONAL COMMUNICATIONS WRIST RADIO	B23	3	2	14	3	9	12	6	28	0.214	1.101	1.212	005.450
64	RADAR HOLOGRAPHER	F6	6	1	5	18	11	5	2	11	0.182	1.168	1.364	001.712
65	MARS POLAR ICE SAMPLE RETURN	D13	3	3	9	7	10	11	4	23	0.174	1.193	1.423	003.353
66	INTERSTELLAR PROBE	D10	2	2	14	4	7	13	5	29	0.172	1.104	1.219	004.529
67	VENUS BALLOON	D42	2	1	9	11	11	8	3	18	0.167	1.098	1.206	002.732
68	LUNAR (OR ASTEROIDAL) STAGING BASE	D75	2	4	8	6	10	12	4	24	0.167	1.239	1.536	003.228
69	U.N. TRUCE OBSERVATION SATELLITE	B6	4	2	9	9	10	10	3	21	0.143	1.153	1.329	002.602
70	SEARCH FOR MARTIAN FOSSILS	D100	2	3	8	8	10	11	3	22	0.136	1.207	1.457	002.486
71	SPACE-BASED SETI	A4	9	4	9	4	9	14	3	27	0.111	1.219	1.487	002.461
72	JUPITER AIRCRAFT	D3	4	2	8	10	10	10	2	20	0.100	1.165	1.358	001.717
73	3-D HOLOGRAPHIC TELECONFERENCING	B25	4	1	10	10	9	10	2	21	0.095	1.091	1.190	001.833
74	MANNED SOLAR ORBITING LABORATORY	D60	3	2	9	7	11	11	2	22	0.091	1.151	1.325	001.738
75	FOOD PRODUCTION IN SPACE	D67	2	2	11	6	8	13	2	26	0.077	1.129	1.274	001.771
76	ENERGY MONITOR	B35	3	2	6	14	9	9	1	17	0.059	1.197	1.434	000.835
77	SEARCH FOR EARTH-APPROACHING ASTEROIDS	D30	2	0	9	13	10	8	1	17	0.059	1.029	1.059	000.972
78	SOLAR SAIL LAGRANGE POINT MISSION	D105	2	0	10	11	10	9	1	19	0.053	1.026	1.053	000.975
79	SPACE DEBRIS SWEEPER	B37	4	0	3	1	33	3	0	6	0.000	1.095	1.200	000.009
80	POWER RELAY SATELLITE	B41	3	2	8	9	9	12	0	22	0.000	1.155	1.333	000.009
81	SPACE OBSERV. OF 3-D LIQ WATER DEN/VEL IN STORMS	A25	5	1	5	16	11	7	0	13	0.000	1.155	1.333	000.009
82	'STANDBY' TRANSPORT OF WATER INTO ORBIT	D16	5	0	2	3	33	2	0	4	0.000	1.155	1.333	000.009
83	MASTER SPACE REFERENCE SYSTEM	A28	3	1	6	15	10	8	0	15	0.000	1.134	1.286	000.009
84	PLANETARY ORBITER MONITORING STATIONS	D39	3	1	9	8	11	11	0	21	0.000	1.095	1.200	000.009
85	SOLARES (REFLECTORS FOR GROUND SOLAR POWER)	A1C	8	3	7	7	9	14	-1	24	-0.042	1.197	1.433	-000.835
86	SEARCH FOR RELATIVISTIC OBJECTS	D109	5	1	7	15	7	10	-1	18	-0.056	1.110	1.232	-000.901
87	PLANETARY SURFACE BEACON NETWORK	A32	4	1	5	16	10	8	-1	14	-0.071	1.141	1.302	-000.876
88	CLIMATE MODIFICATION/HURRICANE SEEDING	A24	7	0	11	5	11	13	-2	24	-0.083	1.018	1.036	-001.965
89	ARTS AND MEDIA REPRESENTATIVES TO ORBIT	D84	3	2	8	8	8	14	-2	24	-0.083	1.139	1.297	-001.756
90	COSMOLOGICAL RANGE FINDER	A22	5	0	8	15	7	10	-2	18	-0.111	1.023	1.046	-001.955
91	AGRICULTURAL ENGINEERING USING REFLECTORS	A1E	5	1	10	6	8	15	-3	26	-0.115	1.071	1.146	-002.801
92	HELIOPAUSE EXPLORER	D1	3	1	2	25	7	5	-1	8	-0.125	1.247	1.554	-000.802
93	UNMANNED PHOBOS LANDER	D82	1	2	4	14	10	10	-2	16	-0.125	1.204	1.450	-001.661
94	ENERGY GENERATION NUCLEAR MICROWAVE	B29	4	2	7	8	9	14	-3	23	-0.130	1.140	1.300	-002.632

TABLE 1 (Cont.)

WEIGHTING FACTORS OUTSTANDING(2),ATTRACTIVE(1),NO OPINION(O), NO RESPONSE(O), UNATTRACTIVE(-1)

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                                                                                                                      PAGE   3
04/30/80                         OAST MISSION OPPORTUNITY RESPONSE ANALYSIS RANKING SCHEDULE
                                               RANKING BY MEAN SCORE

                                                     ID   NO.   NO. OF RESPONSES     TOTAL  NUM    MEAN     STD   VARIANCE     RATIO
   MISSION TITLE                                          LNS    •   +  0  B         SCORE  RESP   SCORE    DEV

 95 PERSONAL NAVIGATION WRIST SET                    B33    3    1   8  9  9 13        -3    22   -0.136   1.082   1.171     -002.773
 96 PARASOL RADIOMETER (10 METER RES L-BAND)         E8     4    0   3 22 11  4        -1     7   -0.143   1.069   1.143     -000.935
 97 NON-TERRESTRIAL MATERIALS FOR TERRESTRIAL USE    A11    7    1   6 14  8 11        -3    18   -0.167   1.098   1.206     -002.732
 98 COMPREHENSIVE SOLAR SYSTEM SAMPLING              D78    3    2   6  8 10 14        -4    22   -0.182   1.140   1.299     -003.509
 99 MANNED LUNAR MISSION USING SHUTTLE ORBITER       D87    3    0   2  2 33  3        -1     5   -0.200   1.095   1.200     -000.913
100 ASTEROID SEARCH SATELLITE                        D72    2    0   6 15 10  9        -3    15   -0.200   1.014   1.029     -002.959
101 LUNAR MINE/FACTORY                               C1     6    0  10  6  9 15        -5    25   -0.200   1.000   1.000     -005.000
102 RAIL ANTI-COLLISION SYSTEM                       B39    4    0  10  6  9 15        -5    25   -0.200   1.000   1.000     -005.000
103 INTERSTELLAR RADAR                               D63    4    1   6 14  7 12        -4    19   -0.211   1.084   1.175     -003.690
104 DETECTION OF EXTRA-PLUTONIAN PLANETS             D8     3    0   5 17 10  8        -3    13   -0.231   1.013   1.026     -002.962
105 LONG BASE-LINE ASTROMETRIC TELESCOPE             D52    4    1   6 13  7 13        -5    20   -0.250   1.070   1.145     -004.673
106 TEXTUROMETER (1MM TO 1M VISIBLE RES)             E4     6    1   1 21 12  5        -2     7   -0.286   1.253   1.571     -001.596
107 1-KM FRESNEL LENS                                A19    6    0   6 16  7 11        -5    17   -0.294   0.985   0.971     -005.076
108 TOURS ABOARD SHUTTLE                             D101   3    0   7  9 10 14        -7    21   -0.333   0.966   0.933     -007.246
109 MANNED MARS AIRPLANE                             D41    3    0   7  7 11 15        -8    22   -0.364   0.953   0.909     -008.395
110 CLIMATE MODIFICATION WITH REFLECTORS             A1D    6    1   5 10  9 15        -8    21   -0.381   1.024   1.048     -007.813
111 BORDER SURVEILLANCE                              B8     4    1   5 11  8 15        -8    21   -0.381   1.024   1.048     -007.813
112 SEARCH FOR SOLAR SYSTEM ACCRETION TAIL           D50    1    0   2 21 12  5        -3     7   -0.429   0.976   0.952     -003.074
113 SPACE SETTLEMENTS                                D26    3    1   6  4  9 20       -12    27   -0.444   0.974   0.949     -012.320
114 UNIVERSITY IN ORBIT                              D85    4    1   5  6  9 19       -12    25   -0.480   0.963   0.927     -012.461
115 RESORT HOTEL IN LOW EARTH ORBIT                  D24    3    1   5  5  8 21       -14    27   -0.519   0.935   0.875     -014.973
116 LOW-FREQUENCY RADIO TELESCOPE/HELIOGYRO          D104   5    0   4 15  7 14       -10    18   -0.556   0.856   0.732     -011.682
117 SHIFT POLLUTING INDUSTRIES OFF EARTH             D59    2    1   4  5  9 21       -15    26   -0.577   0.902   0.814     -016.630
118 LUNAR POWER SYSTEM                               A1B    5    2   2  7  9 20       -14    24   -0.583   0.974   0.949     -014.374
119 NETTA (NIGHT ILLUMINATION)                       A1F   34    1   3 10  8 18       -13    22   -0.591   0.908   0.825     -014.317
120 ASTEROID BEACON NETWORK                          D103   3    0   3 14 10 13       -10    16   -0.625   0.806   0.650     -012.407
121 CLIMATE RESCUE                                   D62    4    1   1 14 11 13       -10    15   -0.667   0.900   0.810     -011.111
122 MANNED INTERSTELLAR MISSION                      D22    1    1   3  4  8 24       -19    28   -0.679   0.819   0.671     -023.199
123 BURGLAR ALARM/INTRUSION DETECTION                B40    4    0   4  6  9 21       -17    25   -0.680   0.748   0.560     -022.727
124 PLANETARY GPS (GLOBAL POSITIONING SYSTEM)        A29    3    0   2 17 10 11        -9    13   -0.692   0.751   0.564     -011.984
125 INTERPLANETARY TV LINK                           B14    3    1   1 14  9 15       -12    17   -0.706   0.849   0.721     -014.134
126 AIRCRAFT LASER POWERING                          B31    3    0   3 10  9 18       -15    21   -0.714   0.717   0.514     -020.921
127 TERRAFORM LARGER CELESTIAL BODIES                D58    3    1   2  5  9 23       -19    26   -0.731   0.778   0.605     -024.422
128 VOTING/POLLING WRIST SET                         B21    3    0   3  5  9 23       -20    26   -0.769   0.652   0.425     -030.675
129 ASTEROID AND COMET DEFLECTION                    D102   2    0   1  9 11 19       -18    20   -0.900   0.447   0.200     -040.268
130 ZERO GRAVITY SPORTS                              D64    2    0   1  6  8 25       -24    26   -0.923   0.392   0.154     -061.224
131 INTERSTELLAR SETTLEMENTS                         D23    1    0   1  4  8 27       -26    28   -0.929   0.378   0.143     -068.783
132 VIEW OF SUN AT A DISTANCE                        D79    2    0   0  3 33  4        -4     4   -1.000   0.000   0.000      000.000
133 SEARCH FOR OORT CLOUD                            D51    5    0   0 21 11  8        -8     8   -1.000   0.000   0.000      000.000
134 VEHICULAR SPEED LIMIT CONTROL                    B36    5    0   0  8  9 23       -23    23   -1.000   0.000   0.000      000.000




WEIGHTING FACTORS: OUTSTANDING( 2),ATTRACTIVE( 1),NO OPINION( 0), NO RESPONSE( 0), UNATTRACTIVE(-1)
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TABLE 1 (Cont.)

TABLE 2

DESCRIPTIONS OF THE 30 TOP RANKED MISSIONS

This table presents the descriptions of the 30 top missons in the ranking presented in Table 1. Descriptions of all the missions voted on are presented in Appendix C.

TABLE 2 (Cont.)

RANKING	MISSION AND DESCRIPTION
1	Permanent Orbiting Outpost (A9, Utilization of Space Environment). A large space structure that is manned. The space station can be equipped with auxiliary modules dedicated to commercial processing; a centralized data processing facility; liquid storage and transfer depot; and maintenance, repair, checkout, and general storage facilities.
2	Landsat H (E1, Resource Observation). Constellation of three multisensor spacecraft with: (1) smart optical sensor that is forward/backward looking and provides 10-m resolution in 10 spectral bands; (2) synthetic aperture radar for all-weather capability; and (3) active visible sensor providing atmospheric calibration, luminescence measurements, and night imaging. All spacecraft are in 700-km sun synchronous orbit and provide 6-day repeat cycle.
3	Geosynchronous Telephone Switching Utility (A13, Communications). A large "switch-in-the-sky" which might lead to a significant reduction in communication costs when large numbers of customers are involved (millions). Possibly associated with a communications platform on which different vendors have equipment and which can be interlinked to avoid additional paths on earth.
4	Geosynchronous Broadband Computer Links (A15, Communications). Multibeam, high-power satellite(s) for interlinking distributed computers at low cost. Provides for a wide range of interactive, ultimately person-centered, computer-aided communication services. Just a few banal examples are: banking; credit transfers; archive access for medical, legal other; and computer mediated conferencing. An important component to implement the concept of freedom of access to information and to each other.
5	International Halley Comet Watch (A31, Solar Terrestrial). Organize an international program of observation of Halley during its next perihelion passage in 1986. Dedicate use of shuttle flights, pallets, spacelab, and space telescope to the endeavor.
6	Ocean Exploration System (A23, Global Environment). Use of space systems to monitor worldwide temperature, salinity, and velocity in the upper ocean mixing layer (100-m deep). Observation of ocean dynamics for climate and other research. Two extremes of technical realization are either 10,000 ocean buoys or remote sounding of oceans. The latter requires considerable R&D for at least 10 years to determine feasibility. Some technical approaches proposed are radar to measure shear in upper 10 ocean meters, and laser pulses to generate internal sound waves and interpret the surface return. A vital measurement is heat flux across the air ocean interface; no potential technique is now known.

TABLE 2 (Cont.)

RANKING	MISSION AND DESCRIPTION
7	Global Search and Rescue Locator (B15, Communications). Coded small transmitter in emergency package carried by boats, aircraft, etc. Signals received and transponded by satellites and location computed by TDOA techniques.
8	Orbiting Civil Command and Control Station (A16, Communications). A concept which exploits space links to: network power; control on sea and land traffic; and support disaster response, policing, and search/rescue.
9	Nuclear Waste Disposal (A2, Utilization of Space Environment). Deposit of radioactive waste in safe long-term positions (0.85 AU orbit, lunar surface, solar escape). Waste mixes range from complete fuel rod assemblies to actinides only. A reasonable mix consists of all long-lived fission products, not including Plutonium, in an oxide form. This represents about 1000 metric tons (MT) cumulative by year 1995. This is derived from a cumulative 50,000 metric tons of discharged uranium (MTU) from a civil US light water reactor industry which is projected then to be 300 GWe (out of 1000 GWe total US capacity all fuels). The 300 GWe capacity gives rise to 5500 MTU per year, which implies about 140 MT per year of waste to dispose. After accounting for shielding, chemical orbital transfer vehicles and safety features, one shutttle flight can dispose of 2.2 MT to 0.85 AU orbit or 0.7 MT to solar system escape. Various heavier lift vehicles would reduce the implied 60 flights per year to perhaps more palatable numbers.
10	Highly Autonomous Tele-Robot (A12, Utilization of Space Environment). Highly autonomous device which accomplishes repetitive tasks in the space environment unburdening man for more productive activity. Its autonomous repertoire would probably be associated with predictable construction/maintenance/production operations.
11	Multiplanet Flybys and Gravity Assist (D40, Planetary). Continued use of gravity assist flyby trajectories. Planetary orbiter missions assisted in unique case-by-case examples.
12	Water Level and Fault Movement Indicator (B3, Solar Terrestrial). Picosecond pulsed laser radar in orbit contains precision differential range measurements from corner reflectors implaced on both sides of faults, river banks and floats, etc.
13	Space-Based Atmospheric Research Facility (A6, Global Environment). Similar to the Astrophysics Research Facility (A5).

TABLE 2 (Cont.)

RANKING	MISSION AND DESCRIPTION
14	Close Solar Orbiter (D47, Solar Terrestrial). Solar circular (perhaps polar) orbiter to monitor changes with high resolution over long time base. Repetitive gravitational data for statistical improvement of J2 data.
15	High Resolution Earth Mapping Radar (B13, Resource Observation). Synthetic array radar of very high power provides high resolution. On-board image processing allows microwave data link for all-weather capability.
16	10-m Optical Interferometer (A17, Astrophysics). A nonredundant array (all possible spacing/orientation combinations of any elements are different) which has about 10 elements and about 10% or less aperture area fill factor. Requires active control of element positioning, particularly when bright sources for direct wavefront sensing are not available in the field. A possible advanced variant which is even more economical in "glass-to-aperture" ratio would involve a nonredundant line array; the aperture limited resolution would be approached by intensity summing of successive images obtained at different rotational orientations of the line aperture about the optical axis. A principal uncertainty with this line aperture approach is whether the successive images can be registered, each to the others, when each image realization of a particular object field is different because the optical transfer function is changing with respect to the object as the line aperture is rotated. Applications include planetary systems, cosmic distance ladder, general relativity (2nd order deflection), and proper motion of galaxies.
17	Evolution of Planetary Exploitation Goals (A34, Planetary). Development of long-term goals for the space agency which recognize a progression from planetary exploration to resource assessment to exploitation.
18	Space-Based Astrophysics Research Facility (A5, Astrophysics). The Astrophysics Space Laboratory represents a highly automated satellite in earth orbit to conduct extensive in-depth surveys of known or suspected objects in the universe. The Astrophysics Laboratory could at times be manned and function as a space station module.
19	Surface Rovers (D49, Planetary). Long-range rovers on planet and satellite surfaces to collect large quantities of varied visual and other in situ data. Mars, Galilean satellites, and other solid-surface bodies.

TABLE 2 (Cont.)

RANKING	MISSION AND DESCRIPTION
20	Transportation Services Satellites (B19, Communications). Similar and overlapping requirements for air traffic control, navigation, position fixing, etc., by many agencies enable one comprehensive system to meet all needs for all users. Comsat transponders are used with four in view of user, or a single orbiting interferometer measures position directly.
21	Automated Planetary Station (A3, Planetary). The station consists of a large highly automated multicomponent spacecraft system capable of conducting a wide range of scientific investigations anywhere in the solar system for about 15-20 years. The main carrier vehicle will serve as a launching and docking platform for the other components of the station as well as a communications relay center. It will conduct scientific explorations and intensive environmental studies using mobile lander vehicles, sample return systems, surface penetrators, atmospheric probes, and fields-and-particles suborbiters. Some key elements in the concept of this station are flexibility, long operating lifetime, and adaptive power. Nuclear electric propulsion (NEP) is proposed for the principal carrier vehicle because of its large payload capacity for outer planets. The major viable alternative is an advanced ballistic concept using Shuttle launches, cryogenic propellants, and VEGA trajectories (Venus-earth garvity assists). A third propulsion concept which is theoretically attractive (at least in the Inner Solar System), but as yet unstudied, is solar sailing.
22	Synchronous Meteorological Satellite (B12, Global Environment). Optical sensor with 1-m mirror collects visible light data on gross meteorological features. Same instrument makes spectrum measurements for detailed information on atmosphere.
23	Space-Based Health Care Research Facility (A7, Life Sciences). The objective of this mission is to develop, evaluate, and optimize the on-board capability for conducting independent bioscience and biomedical experiments. The facility will include a multipurpose laboratory to enable the conducting of biomedical experiments and measurements on men and women as well as on related experimental animals. The focus of these efforts will be on expanding knowledge of the physiological responses of individuals living and working in space for long periods of time. The laboratory will be capable of supporting applied and basic biological, biomedical, behavioral, and technical investigations. The ability to manipulate material directly rather than by automated control alone is an important facet of this facility. The pressurized laboratory concept will constitute a major advance in life sciences investigations in space. In addition to biomedical investigations relevant to man's well being in space, basic principles of biology and medicine can be examined

TABLE 2 (Cont.)

RANKING	MISSION AND DESCRIPTION
23	Space-Based Health Care Research Facility (Cont.) using the zero-gravity environment as a research tool. The laboratory will provide the necessary operational conditions for the evaluation of components of advanced life-support systems and of man-machine integration technology.
24	Detection of Other Planetary Systems (D9, Astrophysics). Several candidate methods.
25	Single-Stage-to-Orbit Shuttle (D97, Space Transportation). Fully reusable, single vehicle transportation system from ground to LEO. Reduced operational complexity.
26	Doppler Millihertz Gravity Wave (A21, Astrophysics). Could be accomplished by deep space Doppler tracking of GHz carrier waves. Detect transient waves where $\Delta \ell / \ell \leq 10^{-12}$. Applications include black hole formation in galactic nucleus.
27	Permanent Lunar Outpost (A8, Planetary). The ultimate goal is a permanently manned lunar base. Amount and frequency of resupply and crew rotation from earth or earth orbit are subject to future study and optimization. For technology purposes, assume on-site crew size fluctuates between 50 and 100 people. This continuous base operation is assumed to be reached via the following stages: (1) lunar polar orbiter survey; (2) automated mobile surface survey; (3) automated precursor processor. The lunar base is both a scientific and manufacturing facility. The scientific areas of interest are astronomy and geology. The astronomical measurements would utilize X-ray, optical, infrared, and radio telescopes. For geological measurements at various sites, instruments capable of drilling to 300 m or more will be necessary, plus a lunar transportation system which would include a shelter that could be used for trips of up to 90 days for a group of scientists. Other lunar base activities will include oxygen production for life support and fuel, food production, and manufacturing of building materials.
28	Advanced Resources/Pollution Observatory (B1, Resource Observation). Active and passive sensors, large aperture, high, medium, and low resolution imaging obtained in multispectral manner. Data disseminated by laser link through relay satellite.

TABLE 2 (Cont.)

RANKING	MISSION AND DESCRIPTION
29	Combined Missions with Primary Engineering and Scientific Objectives (D76, Utilization of Space Environment). Relatively equal emphasis on science and engineering experiments and demonstrations.
30	Operation of Shuttle Out of an Equatorial Launch Site (D18, Space Transportation). Equatorial operation (i.e., Ariane site) would permit maximum utilization of earth's spin. Dogleg maneuvers would be reduced with rendezvous and reentry opportunities increased.

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APPENDIX A
MISSION SELECTION PROCESS

A.1 GENERAL

The process by which the imaginative missions were selected has three features.

First, candidate missions were obtained from seven recent (since 1976) NASA sponsored efforts to identify such new missions (see Sec. A.2.1 and Appendix B).

Second, the candidates were assembled into a nonduplicative list by discipline category without altering their original form (see Sec. A.2.2 and Appendix C).

Third, the missions were voted upon in a subjective, simple way by 41 selected individuals (see Sec. A.2.3 and A.2.4).

The net results of the process are ranked lists of missions from which the representative ranking in Table 1 was selected (see Sec. A-3 and Appendix D).

A.2 DETAILED PROCESS FOR MISSION SELECTION

A.2.1 Imaginative Mission Sources

Imaginative missions can be found in many sources, written and unwritten. The well from which they could be drawn appears unfathomable, its bottom receding as imagination pours out possible goals, applications, technical implementations, and multifaceted variations.

To limit the number of candidate missions while avoiding limitation of imagination, we drew on several previous efforts whose specific raison d'etre had been to identify new missions. The principal sources were:

a. OAST Space Systems Technology Model, Issue 1, October 1978.

b. Briefings from the NASA 1979 Wood's Hole Innovators Group, conducted by the Office of the Chief Scientist.

c. Various missions first proposed, then not validated by the NASA offices for this issue of the Model.

d. Catalog of Initiatives, Volume III of Advanced Space Systems Concepts and Their Orbital Support Needs, by Bekey, Mayer, and Wolfe, April 1976.

e. The JPL Innovation Study of 1979 which paralleled the Wood's Hole Innovators study.

These sources are felt to represent an essentially complete coverage of recent NASA speculative thinking on future civil space activity. Appendix B presents more detail on the sources.

A.2.2 Candidate Mission List Assembly

A total of 205 unique missions were found in the sources. We removed obvious duplicates between sources and with the program office opportunity missions which appear in Volume III, Part A. The aggregate list was thus reduced to 134 missions. These were organized into the

NASA discipline oriented categories (Astrophysics, Planetary, Solar Terrestrial, Life Sciences, Communications, Resource Observation, Global Environment, Space Transportation, Utilization of the Space Environment). Capsule descriptions were prepared to the extent information was available. The resulting set of mission descriptions by category is presented in Appendix C. A brief examination of this set shows how heterogeneous its elements are; goals, applications, and technical approaches are intermixed. We maintained transparency to their original form so this heterogeneity remained apparent. To attempt homogenization appears foolhardy at this stage. Much of the richness of imagination would be lost.

A.2.3 Subjective Voting on Candidate Missions

Thirty-seven individuals were chosen by the major offices (Codes E, M, O, R, S, T) to vote on the candidate missions. Voting consisted of rating each candidate as outstanding, interesting, no opinion, or undesirable. The "ballot" and the voting instructions are in Appendix D,

Four other votes were obtained in an attempt to see if a noticeable divergence occurred between the "officially selected" voters and voters drawn from a more general (but still informed) population. No meaningful divergence was noted; however, this result cannot be considered statistically significant.

No restrictions were placed on voters to remain within their official area of expertise. Most voters did feel comfortable offering opinion on a broad range of candidates.

A.2.4 Compilation of Votes and Result Display

To quantify the voting results, several variations of weights, measures, and voter groupings were used to produce ranked lists of missions.

Weights were assigned to the outstanding, interesting, and undesirable votes: three different weights were used (3, 1, -2), (2, 1, -1), and 2, 2, -2) to help reveal the sensitivity of rankings to the choice of weights.

Three measures of the scores were used to rank the missions. These were, for each weighting:

a. Total score of a mission.

b. Mean score (total score divided by number of outstanding, interesting, and undesirable votes received for that mission).

c. Mean score divided by standard deviation[1] of the sources (standard deviation of the outstanding, interesting, and undesirable scores received for that mission).

The rankings for three weights and three measures were repeated for three different groupings of the voters: all the voters (41), NASA only (37), and NASA planners only (10).

Appendix D presents a selected set of the mission rankings from the 27 rankings produced by the three weights, three measures, and three voter groups.

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[1] Standard deviation is analytically excessive but convenient in the software.

A.3 SELECTION OF THE REPRESENTATIVE RANKING

We selected as most representative the mission ranking resulting from all the votes, mean score, and (2, 1, -1) weight. The logic is detailed in Appendix D. The ranking is presented in Table 1.

A summary of the logic is:

a. Mean score accommodated the fact that all voters did not vote on all missions.

b. The (2, 1, -1) weight resulted in more stable rankings when results from the weights were compared by pairs of rankings.

c. Using all the votes was appropriate for this broad survey of opinion.

A.4 ANALYSIS OF THE RANKING

We cannot presume here to fully interpret the ranking of missions which emerged from the voting. The representative ranking in Table 1 is recommended to technology planners as a guide to priorities when they are making investment decisions. Further commentary in this text on, say, the top 10 missions becomes an advocacy argument which is better left to the technology planners. Some general points should be noted, however.

There is a clear message that the Permanent Orbiting Outpost was favored; it ranked first in any ranking of reasonable statistical significance. This outpost is similar in concept to the Space Operations Center or Space Station endorsed by OSTS over the years. There is apparently a widespread belief in NASA Headquarters that such a permanent presence in space is of considerable importance.

In analysis using these mission rankings, duplication should be considered. Some of these imaginative missions are similar to missions endorsed by the NASA offices in Volume III, Part A. For instance, the 100-m annular telescope is essentially identical to a similar Astrophysics endorsed mission; this is the most obvious case of such duplication. Another type of duplication is among the imaginative missions themselves. For instance, the Space-Based Atmospheric Research Facility and the Space-Based Astrophysics Research Facility are similar in concept and possibly implementation.

The heterogeneity of the forms of the missions presented in the volume should be considered in analysis. If a new mission were to be selected for emphasis on the basis of these voting results, the mission's form needs to be adapted to consider the spirit of the vote and not necessarily the particular description presented.

The selection of the top 30 missions for presentation in Table 2 cuts out many interesting possibilities inherent in lower ranking missions. This cliff-like cutoff at 30 is necessary to limit the size of this volume. The proper, but impractical, approach would be to recognize a slope, not a cliff. The mind of the interested reader can explore such a slope with the data presented in these appendixes.

For some missions which ranked highly, there may be a question of feasibility with which only a few voters were familiar. The prominent example is the Doppler Millihertz Gravity Wave Detection. One voter noted that "the level of sensitivity was probably too low to detect anything." Fourteen individuals voted on this mission, giving it fairly high marks, probably because the description implied it could be accomplished with the current space tracking systems.

Precise future use of the results of this treatment of imaginative missions in this volume of the Model is not clear. If experience to date is a guide, OAST will use the results as one source of "landmark" missions toward which technology development can be aimed. An important early step could be the further definition of the highest ranking missions by means of NASA Phase A study.

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APPENDIX B

IMAGINATIVE MISSION SOURCES

Sources of the candidate imaginative missions were:

A. A list compiled by OAST from the

1. OAST Space Systems Technology Model, Issue I, NASA HQ, October 1978.
2. Briefings from the NASA sponsored 1979 Wood's Hole Innovators Group, conducted by the Office of the Chief Scientist.
3. Various discussions with the NASA program offices.

This list is presented below so the reader can identify the particular origin of mission ideas (38 items[1]).

B. Catalog of Initiatives, Volume III of Advanced Space System Concepts and Their Orbital Support Needs, April 1976, by Bekey, Mayer, and Wolfe (28 items[1]).

C. Space Resources and Space Settlements, NASA SP-428, 1979 (1 item[1]).

D. Space Horizons, JPL Publication 500-150, by J. Beckman, M. Mahlin, and R. Staehle, September 1979 (58 items[1])

E. Post Landsat D, Advanced Concept Evaluation (PLACE), Final Report, General Electric Company, August 1978 (8 items[1]).

F. One instrument (Compton Gamma Ray Polarimeter) rejected by Office of Space Science from its validated list.

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[1] After eliminating duplicates between or within sources, this number of missions from the source appeared in the ballot (Appendix C).

The letters A-F are used as source identifiers in the mission descriptions in Appendix C and in a column on the printouts of mission rankings. The number associated with a letter is a residual from the mission compilation process. It is of little value now in finding a mission description in Appendix C in which missions are grouped by discipline.

SOURCE A

Some Possible Missions for Volume III-B of OAST Space Systems Technology Model

DEC 3 1979

Source of item is shown in ( ); NASA HQ office Code or WH (Woods Hole Innovators Group).

1. Space Solar Energy for Terrestrial Use

Power	Illum
- SPS (R, M)	- LUNETTA (R)
- LPS (R)	
- SOLARES (R)	
- Climate (R)	
- Agricultural Engineering (R)	

2. Nuclear Waste Disposal (M, R)
3. Automated Planetary Station (R, S)
4. Space-Based SETI (R, S)
5. Space-Based Astrophysics Research Facility (R, S)
6. Space-Based Atmosphere Research Facility (R, E)
7. Space-Based Health Care Research Facility (S, R)
8. Permanent Lunar Outpost (R, M, S)
9. Permanent Orbiting Outpost (R)
10. Non-Terrestrial Materials for Space-Based Use (NTM) (R, E)
11. NTM for Terrestrial Use (R, E)
12. Highly Autonomous Tele-Robot (R)
13. Geosynchronous Telephone Switching Utility (R)
14. Geosynchronous Video Broadcast (R)
15. Geosynchronous Broadband Computer Links for Banking; Credit Transfer; archive access for medical, legal, other; computer mediated conferencing; all characterized by very low cost links to permit large fraction of population to participate directly (R)
16. Orbiting Civil Command and Control Station (E, R)
    - Power Networking
    - Traffic Network - air, land, sea
    - Disaster
    - Pollution policing
    - Search and Rescue
17. 10m Optical Interferometer (WH)
18. 100m 2-D Optical Interferometer (WH)
19. 1km Fresnel Lens (WH)
20. Laser Interferometer Gravity Wave (WH)

DEC 3 1975

21. Doppler MilliHz Gravity Wave (WH)
22. Cosmological Range Finder 1000 mpc (WH)
23. 10^4 Ocean Buoys (WH)
24. Climate Mod (WH)
    - Hurricane seeding
25. Space Observation of 3D-liquid water density/velocity in storms (WH)
26. Remote Sounding of Oceans (WH)
27. ΔT cooperative collision avoidance (WH)
28. Master Space ref. sys. (WH)
29. Planetary GPS (WH)
30. Standardized Planetary Mission Hardware (WH)
31. International Halley Comet Watch (WH)
32. Planetary Surface Beacon Network (WH)
33. Deep Probes of Icy Satellites (WH)
34. Evolution of Planetary Exploitation Goals (WH)
35. Manned Planetary (M)

APPENDIX C

IMAGINATIVE MISSION DESCRIPTIONS AND VOTING INSTRUCTIONS

The following list of the imaginative missions was sent to the Associate Administrators of the major operating offices. They subsequently selected individuals from within their organization to vote on the candidates according to these instructions:

> "Please indicate your assessment of the relative attractiveness of each of these missions by marking the master list with the appropriate symbol near the identifying number. The recommended symbols are:
>
> * Outstanding
> \+ Attractive
> o No opinion
> \- Unattractive
>
> Fee free to add your own suggestions for opportunity missions. Criteria you may wish to consider in the assignment of preferences include:
>
> - Merit/utility - is it worth doing?
> - Challenge/feasibility - is it hard but not too hard?
> - Lead time - is it plausible in 1985-2000 time frame?
> - Likelihood - can public support be developed?
> - Articulation - is the concept mature enough to describe?
> - Diversity - is it different from previous or planned missions?
>
> Bear in mind that the primary purpose of this exericise is to establish a key set of opportunity missions which will help identify critical technology development areas. Hence, the required technology for a given mission need not be in hand today."

PLANETARY

A3. Automated Planetary Station. The station consists of a large highly automated multi-component spacecraft system capable of conducting a wide range of scientific investigations anywhere in the solar system for about 15-20 years. The main carrier vehicle will serve as a launching and docking platform for the other components of the station as well as a communications relay center. It will conduct scientific explorations and intensive environmental studies using mobile lander vehicles, sample return systems, surface penetrators, atmospheric probes and fields-and-particles suborbiters. Some key elements in the concept of this station are flexibility, long operating lifetime and adaptive power.

Nuclear electric propulsion (NEP) is proposed for the principal carrier vehicle because of its large payload capacity for outer planets. The major viable alternative is an advanced ballistic concept using Shuttle launches, cryogenic propellants, and VEGA trajectories (Venus-Earth gravity assists). A third propulsion concept which is theoretically attractive (at least in the Inner Solar System), but as yet unstudied, is solar sailing.

A8. Permanent Lunar Outpost. The ultimate goal is a permanently manned lunar base. Amount and frequency of resupply and crew rotation from earth or earth orbit are subject to future study and optimization. For technology purposes, assume on-site crew size fluctuates between 50 and 100 people. This continuous base operation is assumed to be reached via the following stages: (1) lunar polar orbiter survey; (2) automated mobile surface survey; (3) automated precursor processor.

The lunar base is both a scientific and manufacturing facility. The scientific areas of interest are astronomy and geology. The astronomical measurements would utilize X-ray, optical, infrared, and radio telescopes. For geological measurements at various sites, instruments capable of drilling to 300 m or more will be necessary, plus a lunar transportation system which would include a shelter that could be used for trips of up to 90 days for a group of scientists. Other lunar base activities will include oxygen production for life support and fuel, food production, and manufacturing of building materials.

A28. Master Space Reference System. Global Postioning System at Solar system scale; provides both coordinate positions and orientation reference.

A29. Planetary GPS. Global Positioning System in orbit around Mars, etc.

A30. Standardized Planetary Mission Hardware. Standardized components are expected to reduce the cost of future probes. Develop flight hardware for multiple mission use.

A32. Planetary Surface Beacon Network. Develop and deploy solar system wide networks of long-lived reflectors (both active and passive devices considered) on planetary/satellite surfaces to establish intermediate and long-term secular changes.

A33. Deep Probes of Icy Satellites. Consider the development of thermally penetrating probes of icy planetary/satellite surfaces to the depths of 10-100 km to explore deep structure and chemistry of ice-rich layers.

A34. Evolution of Planetary Exploitation Goals. Development of long-term goals for the space agency which recognize a progression from planetary exploration to resource assessment to exploitation.

A35. Manned Planetary Mission (Mars). Today envisioned as a 3 (or more) crew, 30 surface days exploration emphasizing geoscience. Unmanned sample returns would precede. Two year mission duration typical; new technology opportunities since 1969 are aerobraking or aerocapture at Mars and earth return, and propellant manufacture using H_2O and CO_2 on Mars. Artificial low-g and mixed crews are recommended today. Initial earth orbit mass estimated as 2.5 million kg for all chemical, and 1.5 million kg if aerocapture at Mars is used.

D2. Jupiter Atmosphere Balloon. Instrumented hot-air balloon with long residence in jovian atmosphere. Also applicable to other outer planets and Titan.

D3. Jupiter Aircraft. Instrumented aircraft using onboard oxygen or fluorine as "fuel" and ambient hydrogen for propulsion (e.g., jet or propeller engine). Nuclear power also possible for nearly unlimited range. Also applicable to other outer planets and Titan.

D8. Detection of Extra-Plutonian Planets. Multi-spacecraft mission to detect additional planets (if any) in the solar system by tracking gravitational perturbations.

D11. Venus Surface Station. Unmanned, long life automatic station (mobile?) on Venus's surface.

D13. Mars Polar Ice Sample Return. Core samples returned from martian ice caps. Analysis for relic biochemicals, microorganisms, climatic and atmosphere variations.

PLANETARY (Cont.)

D30. Search for Earth-Approaching Asteroids. Ground-based search using telescopes, radar.

D39. Planetary Orbiter Monitoring Stations. Establish and operate at least one unmanned orbiter around all planets at all times for long-term monitoring.

D40. Multiplanet Flybys and Gravity Assist. Continued use of gravity assist flyby trajectories. Planetary orbiter missions assisted in unique case-by-case examples.

D41. Manned Mars Airplane.

D42. Venus Balloon. Long duration instrumented (perhaps manned) balloon in Venusian atmosphere.

D43. Venus "Bathysphere". Pressure and temperature-protected vehicle for instrumented or manned sorties to Venusian surface.

D44. Comet "Piggyback" Probe. Spacecraft intercepts and attaches to long-period comet for in situ measurements or transportation out of solar system.

D49. Surface Rovers. Long-range rovers on planet and satellite surfaces to collect large quantities of varied visual and other in situ data. Mars, Galilean satellites, and other solid-surface bodies.

D71. Catalog of Solar System Resources. Measure "inventory" of valuable resources in solar system to plan effective utilization.

D72. Asteroid Search Satellite. Operate IR and/or optical telescope in earth orbit to search for small asteroids.

D78. Comprehensive Solar System Sampling. Sample return from every major solid body in the solar system, and selected asteroid and comet samples.

D82. Unmanned Phobos Lander. Martian observatory.

D102. Asteroid and Comet Deflection. Change orbits of potentially threatening asteroids and comets to prevent impact with earth.

PLANETARY (Cont.)

D103. Asteroid Beacon Network. Network of active transponders and passive reflectors on asteroids to track establish long-term orbital variations.

D105. Solar Sail Lagrange Point Mission. Simple mission to Earth-Moon Lagrange points to search for trapped dust, debris.

ASTROPHYSICS

A5. Space-Based Astrophysics Research Facility. The Astrophysics Space Laboratory represents a highly automated satellite in Earth orbit to conduct extensive in-depth surveys of known or suspected objects in the universe. The astrophysics laboratory could at times be manned and function as a space station module.

A17. 10-m Optical Interferometer. A nonredundant array (all possible spacing/orientation combinations of any elements are different) which has about 10 elements and about 10% or less aperture area fill factor. Requires active control of element positioning, particularly when bright sources for direct wavefront sensing are not available in the field. A possible advanced variant which is even more economical in "glass-to-aperture" ratio would involve a nonredundant line array; the aperture limited resolution would be approached by intensity summing of successive images obtained at different rotational orientations of the line aperture about the optical axis. A principal uncertainty with this line aperture approach is whether the successive images can be registered, each to the others, when each image realization of a particular object field is different because the optical transfer function is changing with respect to the object as the line aperture is rotated. Applications include planetary systems, cosmic distance ladder, general relativity (2nd order deflection) and proper motion of galaxies.

A18. 100-m 2-D Optical Interferometer. Ring or cross. Resolution of 10^{-3} arc sec. Applications include galactic cores, quasars, superluminal sources and planetary systems. Narration for #17 applies.

A19. 1-km Fresnel Lens. One implementation would be inflatable bag with aluminized stripes. 100-km focal length (f/100). One centimeter wavelength. Sensors on 10-m diameter station keeping platforms, with position tolerances of 1 m transverse to 30 m along optical axis. Applications include galactic cores, pulsars, quasars, superluminal sources. May answer open or closed universe question.

A20. Laser Interferometer Gravity Wave. Seek kHz gravitational waves by laser interferometer in earth orbit. Detect transient waves where $\Delta\ell/\ell \leq 10^{-20}$. Applications include supernova collapse detection.

A21. Doppler Millihertz Gravity Wave. Could be accomplished by deep space Doppler tracking of GHz carrier waves. Detect transient waves where $\Delta\ell/\ell \leq 10^{-12}$. Applications include black hole formation in galactic nucleus.

ASTROPHYSICS (Cont.)

A22. Cosmological Range Finder. Universe hypothesized size is 18,000 mega light years (about 6000 mega parsec). In this concept, distances up to 1000 mega parsec are measured in the classical range finder sense, i.e., by measuring the angle between two optical axes, separated by 10 astronomical units.

D1. Heliopause Explorer. Fields and particles-oriented mission to reach heliopause as fast as possible, characterize the heliopause region and the interstellar medium.

D6. Lunar Farside Radio Telescope. Large radio telescope free of terrestrial interference. Many applications.

D9. Detection of Other Planetary Systems. Several candidate methods.

D10. Interstellar Probe. Unmanned expedition to a near star and its (assumed) planets.

D52. Long Base-Line Astrometric Telescope. Build spaceborne astrometric telescope for launch to ≥ 5 AU orbit. Increases base line for stellar parallax measurements. Present base line is 2 AU using earth's orbit around sun.

D63. Interstellar Radar. Apply radar techniques to detection of extra-solar planets and other measurements of stars and stellar systems. Transmissions may be made several years in advance of capability to detect return echo.

D89. Confirmation of Black Holes. Utilization of spaceborne instrumentation to confirm theoretical developments and resolve questions surrounding black hole investigations. Finer spatial resolution, open spectrum, and longer observing periods enhance space capabilities for a range of applicable instruments.

D90. Very Large Annulus Optical Telescope. Construct very large aperture optical telescope using large space structures-supported annular ring of smaller mirrors. Very high angular resolution.

D104. Low-Frequency Radio Telescope/Heliogyro. Use of inherent large heliogyro dimensions and maneuverability as a large, steerable low frequency radio telescope. Operation in spectral ranges blocked by earth's atmosphere. Possible positioning of later versions in outer solar system to reduce heliosphere attenuation.

D109. Search for Relativistic Objects. Develop instrumentation and procedures to detect relativistic objects ($\geq$ 0.05c) traveling through solar system. Such objects may now be undetectable. Possibility of intelligent origin. Also search for signs of past collisions by such objects with natural bodies.

F1. Gamma Ray Compton Telescope and Polarimeter. An instrument employing Compton scattering to detect gamma rays; extends gamma ray measurements to include polarization.

SOLAR TERRESTRIAL

A31. International Halley Comet Watch. Organize an international program of observation of Halley during its next perihelion passage in 1986. Dedicate use of shuttle flights, pallets, spacelab and space telescope to the endeavor.

B3. Water Level and Fault Movement Indicator. Picosecond pulsed laser radar in orbit obtains precision differential range measurements from corner reflectors implaced on both sides of faults, river banks and floats, etc.

D46. Solar Penetrator. High velocity automated probe drops as far into sun as possible telemetering real-time data until destruction. Perhaps several at different locations and features.

D47. Close Solar Orbiter. Solar circular (perhaps polar) orbiter to monitor changes with high resolution over long time base. Repetitive gravitational data for statistical improvement of J2 data.

D50. Search for Solar System Accretion Trail.

D51. Search for Oort Cloud. Observation of hypothesized "cloud" of comets of outer solar system (beyond Pluto). Often assumed to be source of comets, existence disputed. Could use telescopes for optical or radio evidence, or perhaps spacecraft for in situ measurement.

D60. Manned Solar Orbiting Laboratory. Multipurpose instrumented observatory and laboratory to gather data and conduct experiments regarding the sun and its output.

D79. View of Sun at a Distance. Acquire image of sun at great distance to show as a star. Similar to first whole-earth picture.

D108. Icarus "Peek-a-Boo" Mission. Spacecraft "hides" in shadow of asteroid Icarus during close pass by sun. May frequently emerge from shadow to view sun, then retreat to shade.

LIFE SCIENCES

A4. Space-Based SETI (Search for Extraterrestrial Intelligence.) Placed at great range from earth and employing artificial or natural (moon) shielding against electromagnetic interference, a microwave listening facility has the potential to achieve sensitivities far in excess of terrestrial systems. While considerable evaluation remains to be done, a space-based system appears more cost effective if search is to be extended beyond about 500 light years. Nominal antenna size is 300 m and a receiver temperature of 10° K at 1.5 GHz.

A7. Space-Based Health Care Research Facility. The objective of this mission is to develop, evaluate, and optimize the on-board capability for conducting independent bioscience and biomedical experiments. The facility will include a multipurpose laboratory to enable the conducting of biomedical experiments and measurements on men and women as well as on related experimental animals. The focus of these efforts will be on expanding knowledge of the physiological responses of individuals living and working in space for long period of time.

The laboratory will be capable of supporting applied and basic biological, biomedical, behavioral, and technical investigations. The ability to manipulate material directly rather than by automated control alone is an important facet of this facility. The pressurized laboratory concept will constitute a major advance in life sciences investigations in space. In addition to biomedical investigations relevant to man's well being in space, basic principles of biology and medicine can be examined using the zero-gravity environment as a research tool. The laboratory will provide the necessary operational conditions for the evaluation of components of advanced life-support systems and of man-machine integration technology.

D38. Search for Life. Continued search for life of nonterrestrial origin in solar systems.

D100. Search for Martian Fossils. Search for evidence of past life on Mars in sedimentary and extrusive units.

RESOURCE OBSERVATION

B1. Advanced Resources/Pollution Observatory. Active and passive sensors, large aperture, high, medium and low resolution imaging obtained in multispectral manner. Data disseminated by laser link through relay satellite.

B2. Fire Detection. Satellite with short and long wave infrared sensors detects fires at an early stage - transmits data to control center.

B13. High Resolution Earth Mapping Radar. Synthetic array radar of very high power provides high resolution. On-board image processing allows microwave data link for all weather capability.

E1. Landsat H. Constellation of three multisensor spacecraft with: (1) smart optical sensor that is forward/backward looking and provides 10-m resolution in 10 spectral bands; (2) synthetic aperture radar for all weather capability; and (3) active visible sensor providing atmospheric calibration, luminescence measurements and night imaging. All spacecraft are in 700-km sun synchronous orbit and provide 6-day repeat cycle.

E2. Earthwatch. Constellation of 8-12 spacecraft in 55 degree, 10,000-km orbit providing near continuous coverage. Sensor complement includes two pointable optical sensors, one for mapping (30-m ground resolution) and one with high resolution for quick-look disaster assessment. Also included are two microwave sensors, one synthetic aperture radar and one microwave radiometer (ground resolution is 10-25 m and 12-120 km, respectively).

E3. GEOS. Geostationary Earth Observation Satellite. Main reflector diameter of 8 m allows a 3-m instantaneous field of view in the visible with a 24-m focal length.

E4. Texturometer. Three lines of mirrors provide required resolution in 3 directions, 60 degrees apart. Each line is composed of segmented spherical mirrors. The thousand sensors in each line produce output that may be mathematically transformed to indicate ground texture. Visible texture from 1 mm to 1 m observed from 600-km orbit.

E5. Thermal Inertia Mapper. Resolution of 10 m from 600-km orbit (sun synchronous) in 10.5 to 12.5 micrometer band. Designed to measure thermal inertia with 0.1° C precision. HCMM follow-on.

E6. Radar Holographer. Stable 300 MHz transmitter in geosynchronous oribt; a number of simple receiver satellites in low earth orbit measure phase and amplitude of the earth return relative to the direct illuminator signal. True hologram output would be particularly valuable for those applications requiring topographic information and a variable perspective.

7. Microsat. The prime function of the Microsat system is the measurement of soil moisture with 1-km ground resolution. An L-band radiometer is used to obtain 1K radiometric temperature resolution. Antenna is a parabolic torus with a cluster of feed horns arranged in a focal arc; reflector size is 600 m by 1300 m.

8. Parasol Radiometer. A 10-km circular phased array passive radiometer operating at 10-cm wavelength. Resolution from 1000-km orbit is 10 m. Rigid structure has active shape and attitude control system.

GLOBAL ENVIRONMENT

A6. Space-Based Atmospheric Research Facility. Similar to the Astrophysics Research Facility (A5).

A23. Ocean Exploration System. Use of space systems to monitor worldwide temperature, salinity, and velocity in the upper ocean mixing layer (100 m deep). Observation of ocean dynamics for climate and other research. Two extremes of technical realization are either 10,000 ocean buoys or remote sounding of oceans. The latter requires considerable R&D for at least 10 years to determine feasibility. Some technical approaches proposed are radar to measure shear in upper 10 ocean meters, and laser pulses to generate internal sound waves and interpret the surface return. A vital measurement is heat flux across the air ocean interface; no potential technique is now known.

A24. Climate Modification/Hurricane Seeding. Present work (Storm Fury) shows some possibility to mollify or steer hurricanes. It is difficult to maintain ground crew and airplanes in readiness, and also difficult to identify and seed suitable storms. Consequently, the rate of acquisition of data is very low. One implementation is 100 kg entry vehicle, 500 kg of A_gI_2 in hermite bombs with simple guidance system. Ballistic missile delivery also possible.

A25. Space Observation of 3-D Liquid Water Density/Velocity in Storms. Use two multifrequency active radars operating in the 20-10 cm wavelength region with 100-m antenna to make 3-dimensional studies of wind velocities and the amount of liquid water in storms. Smaller (0.1 the size) ground-based systems will work also.

B11. Atmospheric Temperature Profile Sounder. Pulsed laser vibrationally excites CO_2 or H_2O molecules. Subsequent rotational transitions in the millimeter wave spectrum show temperature dependence which is measured by ratio of energy in several lines.

B12. Synchronous Meteorological Satellite. Optical sensor with 1-m mirror collects visible light data on gross meteorological features. Same instrument makes spectrum measurements for detailed information on atmosphere.

B38. Ozone Layer Replenishment/Protection. Space shuttle or heavy lift booster dispenses a chemical which settles and catalyzes the binding of free chlorine atoms produced by the freon, preventing the chlorine from destroying ozone.

D62. Climate Rescue. Design equipment and procedures, including spaceborne systems to prevent disasterous climatic perturbations such as might be precipitated by volcanic injection of dust into the stratosphere as with Krakatoa.

COMMUNICATIONS

A13. Geosynchronous Telephone Switching Utility. A large "switch-in-the-sky" which might lead to a significant reduction in communication costs when large numbers of customers are involved (millions). Possibly associated with a communications platform on which different vendors have equipment and which can be interlinked to avoid additional paths on earth.

A15. Geosynchronous Broadband Computer Links. Multibeam, high-power satellite(s) for interlinking distributed computers at low cost. Provides for a wide range of interactive, ultimately person-centered, computer-aided communication services. Just a few banal examples are: banking; credit transfers; archive access for medical, legal, other; and computer mediated conferencing. An important component to implement the concept of freedom of access to information and to each other.

A16. Orbiting Civil Command and Control Station. A concept which exploits space links to: network power; control on sea and land traffic; and support disaster response, policing, and search/rescue.

A27. Time Difference Cooperative Collision Avoidance. One possible implementation is discussed in Item B-39.

B14. Interplanetary TV Link. Live, 60-frame-per-sec color TV transmitted over 20 million miles to 60-ft ground antennas. Four inch diameter optic and 10 W laser output suffice in transmitter.

B15. Global Search and Rescue Locator. Coded small transmitter in emergency package carried by boats, aircraft, etc. Signals received and transponded by satellites and location computed by TDOA techniques.

B16. Urban/Police Wrist Radio. Wrist 2-way transceiver and channelized Comsat give instant communications to patrolmen. Multibeam antenna, anti-jam processing and pseudo-random coding make jamming difficult.

B17. Disaster Communications Set. Wrist 2-way transceivers connected to each other and control centers through multichannel Comsat.

B19. Transportation Services Satellites. Similar and overlapping requirements for air traffic control, navigation, position fixing, etc., by many agencies enable one comprehensive system to meet all needs for all users. Comsat transponders are used with four in view of user, or a single orbiting interferometer measures position directly.

B21. Voting/Polling Wrist Set. Multichannel satellite queries wrist radios and relays responses to Washington from individual voters. Unique voter pseudo-random codes.

COMMUNICATIONS (Cont.)

B23. Personal Communications Wrist Radio. Multichannel switching satellite and wrist transmitters/receivers connect people anywhere to each other directly.

B24. Diplomatic/UN Hotlines. Provides rapid, reliable, secure communications between heads of state, embassies, other international actors.

B25. 3-D Holographic Teleconferencing. Identical conference rooms are fitted with TV camera, projector, laser illuminator and stereo sound to produce holograms of 3-dimensional images that walk and talk.

B33. Personal Navigation Wrist Set. Narrow beams are swept over the US by large phased arrays in space. Very simple receivers measure time elapsed between pulses and display distances to fixed objects.

B35. Energy Monitor. Small L-band transmitters send instantaneous current, voltage or power readings on network when queried sequentially by multichannel/processing communications repeater.

B36. Vehicular Speed Limit Control. Each vehicle has a small transceiver and a command receiver connected to a commandable speed governor. Each vehicle's position is determined using crossed antenna NAVSAT (interferometer). Speed commands are generated by computer on the ground.

B39. Rail Anti-Collision System. Each train has a small beacon and command receiver. Location of each train is continuously computed on the ground using TDOA and upon detection of a collision course, alerting buzzer in train is sounded.

B40. Burglar Alarm/Intrusion Detection. Very many very small seismic or discrete sensors transmit when activated. Signals picked up by single large antenna satellite for all of US, and relayed to police command post nearest to area intruded.

SPACE TRANSPORTATION

B37. Space Debris Sweeper. Use tug to impart velocity change to synchronous debris to drop its perigee to less than 100 n mi. Debris will reenter within weeks. One orbit later tug reinjects itself to synchronous orbit. Tug resupplied by shuttle.

D16. "Standby" Transport of Water into Orbit. Most Shuttle flights are likely to have small mass and volume margins. Filling these margins with water in tanks to be left in orbit would enable a ready supply at low cost. Hydrolysis or direct use would yield propellants, consumables, and process materials.

D18. Operation of Shuttle Out of an Equatorial Launch Site. Equatorial operation (i.e., Ariane site) would permit maximum utilization of earth's spin. Dogleg maneuvers would be reduced with rendezvous and reentry opportunities increased.

D86. Super-Synchronous Junkyard. Repository for unneeded or inert space hardware which could interface with operating satellites in geostationary orbit. Unused hardware is gathered and fastened to single large structure, may also be conveniently "cannibalized" for any components of value.

D87. Manned Lunar Mission Using Shuttle Orbiter. Refuel ET and/or add OMS kits in orbit, fly crew to moon, then return to earth with direct entry out of trans-earth trajectory.

D97. Single-Stage-to-Orbit Shuttle. Fully reusable, single vehicle transportation system from ground to LEO. Reduced operational complexity.

UTILIZATION OF SPACE ENVIRONMENT

A1a. Solar Power Satellite. A space system with near continuous sun exposure for producing power to beam to terrestrial networks. Base-line system is 5 GWe DC at output of ground rectennas with photovoltaic conversion in space. Solar flux to terrestrial DC overall efficiency is 7%. Major elements of base line are 50 km^2 array size, 1-km diameter 2.5 GHz transmitter using $1\text{-}2 \times 10^5$ klystrons, satellite mass of $30\text{-}50 \times 10^6$ kg, ground rectenna size 10 × 13 km with 25 billion rectifier elements.

A1b. Lunar Power System. Similar to Satellite Power System except that solar arrays are on the moon surface, exploiting trenches to provide structure and native iron for conductors. The microwave transmitter would have to be ten times the diameter of a geosynchronous transmitter, i.e., lunar transmitter has 10-km diameter.

A1c. SOLARES. A system of orbiting mirrors for delivering enhanced insolation for various purposes, particularly power generation. Various first-order energy, orbit and dynamic factors lead to a point design featuring 1 km^2 mirrors at 0.1 GEO, 80,000 in number feeding 1 sun (1 kW/m^2) to a 50-km diameter solar farm yielding 200 GWe. Five such solar farms could be operated world-wide, producing 1000 GWe. (This compares with current US capacity of about 500 GWe and world capacity of about 1500 GWe.)

A1d. Climate. This concept involves orbiting solar reflectors to increase the earth surface flux to modify climate. We are not aware of studies to find the significant parameters; we assume that a 10% increase in flux would be required to achieve a significant effect over a 400-km diameter circle. About $10^3/km^2$ of reflector at GEO is required to achieve 10% increase in average flux.

A1e. Agricultural Engineering. This concept again involves orbiting solar reflectors to increase the earth surface flux to enhance agricultural productivity. We are not now aware of studies to find the significant parameters; any such study would be complicated by the wide range of possible effects, intended and unintended.

A1f. Lunetta. This concept involves geosynchronous reflectors to provide nighttime illumination, not thermal effects. The area illuminated has a diameter of about 400 km, physically not reducible. A 300-m diameter reflector at GEO provides 0.01 $lumen/ft^2$ (full moon). One $lumen/ft^2$ equals highway lighting and 5 $lumen/ft^2$ equals bright street lighting. Reflectors might be solar sailable to geosynchronous orbit (2-3 years transit). Annual lighting cost in New York-Washington corridor is estimated at $400 M; reflector benefit depends on degree of substitution.

UTILIZATION OF SPACE ENVIRONMENT (Cont.)

A2. Nuclear Waste Disposal. Deposit of radioactive waste in safe long-term positions (0.85 AU orbit, lunar surface, solar escape). Waste mixes range from complete fuel rod assemblies to actinides only. A reasonable mix consists of all long-lived fission products, not including Plutonium, in an oxide form. This represents about 1000 metric tons (MT) cumulative by year 1995. This is derived from a cumulative 50,000 metric tons of discharged uranium (MTU) from a civil US light water reactor industry which is projected then to be 300 GWe (out of 1000 GWe total US capacity all fuels). The 300 GWe capacity gives rise to 5,500 MTU per year, which implies about 140 MT per year of waste to dispose. After accounting for shielding, chemical orbital transfer vehicles and safety features, one shuttle flight can dispose of 2.2 MT to 0.85 AU orbit or 0.7 MT to solar system escape. Various heavier lift vehicles would reduce the implied 60 flights per year to perhaps more palatable numbers.

A9. Permanent Orbiting Outpost. A large space structure that is manned. The space station can be equipped with auxiliary modules dedicated to commercial processing; a centralized data processing facility; liquid storage and transfer depot; and maintenance, repair, checkout, and general storage facilities.

A10. Non-Terrestrial Materials for Space Use. Use of lunar materials for extensive space activity has the advantage of 20 times lower transportation energy to reach space, logically Lagrangian point 4 or 5. 98% of mass of chemical elements, exclusive of petroleum, which composed the US industrial feedstock in 1968 can be obtained from the pulverized lunar soil. New processing technology, with potential spinoffs to earth, are needed. Space colonies which produce Solar Power Systems to provide earth with power are commonly envisioned now as the means to exploit lunar resources.

A11. Non-Terrestrial Materials for Terrestrial Use. Terrestrial raw materials might be supplemented with space materials. As an example, the asteroid population is believed to contain iron-nickel bodies which are of direct use on earth. A 1 cubic km body is valued at $1 trillion, and satisfies earth demand for 10 years. Orbit transfer might be accomplished by nuclear explosion impulses or by mass drivers.

A12. Highly Autonomous Tele-Robot. Highly autonomous device which accomplishes repetitive tasks in the space environment unburdening man for more productive activity. Its autonomous repertoire would probably be associated with predictable construction/maintenance/production operations.

UTILIZATION OF SPACE ENVIRONMENT (Cont.)

B6. U.N. Truce Observation Satellite. One low-altitude satellite with visible light optics for daytime monitoring and infrared optics for nighttime operation. Aids U.N. teams to monitor truce agreements, particularly border zones.

B7. Nuclear Fuel Locator. To detect and locate all nuclear reactor fuel elements continuously. Each assembly or container is tagged with a microwave generator in a tamper indicating case. The uniquely coded signals are transponded by four satellites and the position computed by time-difference-of-arrival on the ground.

B8. Border Surveillance. Very many very small seismic sensors are read out by a satellite with very large antenna. Penetration causes vibrations which are picked up and correlated at a central site.

B29. Energy Generation - Nuclear Microwave. A breeder reactor, MHD generator, microwave transmitter and antenna are used to beam energy to ground receiver. 5000 MW with fuel breeding life of 1000 yr.

B31. Aircraft Laser Powering. Jet turbines are operated by heating air with laser beams projected to each aircraft by multimirror satellites. Laser on ground powered by nuclear reactors.

B41. Power Relay Satellite. Source power is converted to microwave beam bounced off an orbiting reflector and reconverted to DC at receiving antenna on the ground.

C1. Lunar Mine/Factory. Lunar base powered by solar arrays on lunar surface illuminated by reflectors in lunar orbit; extracts lunar soil for use or shipment. Shipment is by packaging for launch by electromagnetic mass driver. Deployed by 25 persons in 4 months, maintained by 10 persons. Initial productivity of 30,000 tons/year can be expanded in 5 years to 600,000 tons/year.

D24. Resort Hotel in Low Earth Orbit. Tourism promoted into low earth orbit. Pleasures of view, weightlessness, uniqueness and novelty of experience, intrigue of other orbital operations seen firsthand.

D26. Space Settlements. Permanent, largely self-sufficient sociopolitical and ecological units in large (km) structures rotating in free space for artificial gravity.

D59. Shift Polluting Industries off Earth. Move harmful industries out of biosphere so pollutants are not environmentally damaging.

UTILIZATION OF SPACE ENVIRONMENT (Cont.)

D64. Zero Gravity Sports. Games and sports adapted and invented to take advantage of zero gravity.

D67. Food Production in Space. Growth of crop plants in space, development of growth and harvesting techniques.

D75. Lunar (or Asteroidal) Staging Base. Provisioning, fueling, and assembly base for expeditionary spacecraft.

D76. Combined Missions with Primary Engineering and Scientific Objectives. Relatively equal emphasis on science and engineering experiments and demonstrations.

D84. Arts and Media Representatives to Orbit. Flight opportunities for poets, artists, and photographers aboard Shuttle to broaden their experience and help relate space to nontechnical people.

D85. University in Orbit. Complete educational institution in orbit for learning and cultural experience. Innovation and in-depth understanding of space environment results from diversity of people living in space for long periods in an educational atmosphere.

D101. Tours Aboard Shuttle. Privately operated vacation-type excursions aboard Orbiter with appropriate modules. Later use with manned orbital stations.

D22. Manned Interstellar Mission.

D23. Interstellar Settlements.

D58. Terraform Larger Celestial Bodies. Begin process of converting or adding atmosphere on Mars, Venus, or Moon to become habitable by humans and other organisms.

APPENDIX D

OTHER RANKINGS OF IMAGINATIVE MISSIONS

Table D.1 presents the selected representative ranking. This appendix presents additional rankings from the 27 produced from the votes. Also presented within this appendix are the statistics on the individual voters (with anonymity maintained).

LOGIC FOR SELECTION OF REPRESENTATIVE RANKING

The ranking resulting from the (2, 1, -1) weights, mean score as the measure, and the group of all the voters appeared closest to being most representative.

Mean score was necessary to accommodate the fact that each voter did not vote on every mission.

The choice of the (2, 1, -1) weighting was based on the stability of rankings as the weights were changed. The stability was measured by finding the average (signed), absolute average, and associated standard deviations of the rank shifts of the top thirty missions on one list compared to their positions on another list. This approach yields, theoretically, about 3000 numbers to be considered in determining stability for the 27 rankings. To find a reasonable course through this labyrinth, we made the assumption that the mean score was most representative. Then the (2, 1, -1) weight was chosen by observing that the ranks resulting from it differed least from the ranks resulting from the other weights. Specifically, the rank of the top 30 missions from the mean score and all voters was compared for the three different weights, resulting in the signed averages and absolute averages with associated standard deviations presented in Table D.1.

Based on the statistics of Table D.1, a strong argument can be made that the (2, 2, -2) weighting leads to greater instability in ranks compared to the (3, 1, -2) or (2, 1, -1) weightings. The choice between (3, 1, -2) and (2, 1, -1) is not so clear. (2, 1, -1) was chosen because

TABLE D.1

COMPARISON OF RANK OF TOP THIRTY MISSIONS BY WEIGHTINGS; MEAN SCORE, ALL VOTERS

The ranks of the top 30 on these lists→ were subtracted from the rank of appearance on these lists↓	WEIGHT (3,1,-2)	WEIGHT (2,1,-1)	WEIGHT (2,2,-2)
(3,1,-2)	X	0.066, 1.57 1.13, 1.07	2, 7.87 5.93, 5.45
(2,1,-1)	0.066, 1.57 1.13, 1.07	X	Not Done
(2,2,-2)	Not Done	2, 6.78 5.13, 4.78	X

Key to Rank Shifts Statistics

Signed

Average Shift, Standard Deviation of Shifts

Absolute

Average Shift, Standard Deviation of Shifts it led to slightly less shifting overall in these paired comparisons. Another way to state the situation is this: of the top 30 missions for the (2, 1, -1) weighting, these same missions also appear as the top 30 of the (3, 1, -2) weighting, and 26 appeared in the top 30 of the (2, 2, -2) weighting.

Having selected mean score with (2, 1, -1) weighting, the next question was which group of voters was most representative. The top 30 missions for all voters (41) compared to the NASA voters (37) had a signed average rank shift of 0.5 with a standard deviation of 3 ranks. Of the top 30 for all voters, 28 were common with the top 30 for the NASA voters. We concluded there was no significant difference in the rankings from these two larger groupings of the voters.

The ranking by the 10 planners did show significant shifts relative to the two larger groupings of voters. The top 30 missions for all voters compared with the planners had a signed average shift of 14 ranks with a standard deviation of 19 ranks, and an absolute average shift of 19 ranks with a standard deviation of 13. Of the top 30 missions for all the voters, the 10 planners included only 18 in their top 30. Since the average number of planner votes was only 4 (range of 7 to 2) for the planners' top 30 missions, the resulting planner rankings contain considerable statistical noise and hence were not considered the best representative rankings for this volume.

Consequently, we chose the ranking from all the voters as the best consensus on the ranking of the imaginative missions.

Subsequent tables in this appendix present the first page (47 missions) of some selected rankings which seem of interest for further comparative analysis by interested readers. These rankings are:

best copy available

a. All voters (41), mean score

Table D.2: (3, 1, -2) weight
Table D.3: (2, 2, -2) weight

b. All voters (41), (2, 1, -1) weight

Table D.4: total score
Table D.5: total score/standard deviation

c. Table D.6: NASA voters only (37), mean score, (2, 1, -1) weight

d. Table D.7: planners only (10), mean score, (2, 1, -1) weight (all three pages of rankings are presented)

Table D.8 presents data on the scores of the individual voters by discipline. The planners were voters 10, 11, 20, 24, 32, 33, 34, 35, 36, 41. Remove voters 21, 22, 23, 30 to obtain the NASA only group. The mean of the individual voter means is 0.135 with a standard deviation of 0.52, for the (2, 1, -1) weighting. Not apparent in the numbers was the enthusiasm many voters put into their task. This enthusiasm was not universal, however; voter 31 does not appear in Table D.8 because he refused to vote. Voter 40 voted but turned in only blanks or "no opinions." On balance, it seems the voters, considered as a whole group, represented a suitable varied population for the purpose of ranking the diverse candidate missions.

DEFINITION OF COLUMN HEADINGS ON PRINTOUTS OF MISSION RANKINGS

MISSION TITLE:	A short descriptive name.
ID:	An identifier left over from the original selection of missions from the sources (see Appendix C).
NO. LNS:	The number of lines in a mission description on the ballot. Useful for detecting connection between rank and quantity of description.
NO. OF RESPONSES:	The number of outstanding (*), interesting (+), no opinion (o), blank (B), or negative (-) responses received for that mission.
TOTAL SCORE:	The sum of the score using the weights presented at the bottom of the printouts.
NUM RESP:	Number of voters who gave an opinionated vote on the mission (*, +, or -).
MEAN SCORE:	The total score divided by the number of opinionated votes received for that mission.
STD DEV:	Standard deviation of the opinionated vote scores.
VARIANCE:	Standard deviation squared.
RATIO:	Total score divided by standard deviation.

04/30/80

OAST MISSION OPPORTUNITY RESPONSE ANALYSIS RANKING SCHEDULE
RANKING BY MEAN SCORE

MISSION TITLE	ID	NO. LNS	NO. OF RESPONSES					TOTAL SCORE	NUM RESP	MEAN SCORE	STD DEV	VARIANCE	RATIO
			*	+	0	B	-						
1 PERMANENT ORBITING OUTPOST	A9	5	18	10	3	8	1	62	29	2.138	1.246	1.552	049.759
2 INTERNATIONAL HALLEY COMET WATCH	A31	4	13	9	6	9	3	42	25	1.680	1.676	2.810	025.060
3 LANDSAT H.(10-M RES ACTIVE/PASSIVE OBSERVATIONS)	E1	7	7	14	9	10	0	35	21	1.667	0.966	0.933	036.232
4 GEOSYNCHRONOUS TELEPHONE SWITCHING UTILITY	A13	6	10	15	5	9	1	43	26	1.654	1.231	1.515	034.931
5 GEOSYNCHRONOUS BROADBAND COMPUTER LINKS	A15	8	8	19	4	9	0	43	27	1.593	0.931	0.866	046.187
6 OCEAN EXPLORING SYSTEM	A23	11	9	16	3	11	1	41	26	1.577	1.206	1.454	033.997
7 NUCLEAR WASTE DISPOSAL	A2	15	13	10	5	8	4	41	27	1.519	1.762	3.105	023.269
8 ORBITING CIVIL COMMAND AND CONTROL STATION	A16	4	8	10	11	9	2	30	20	1.500	1.539	2.368	019.493
9 GLOBAL SEARCH AND RESCUE LOCATOR	B15	4	6	21	4	9	0	39	27	1.444	0.847	0.718	046.045
10 HIGHLY AUTONOMOUS TELE-ROBOT	A12	5	10	14	5	8	3	38	27	1.407	1.551	2.405	024.500
11 SPACE-BASED ATMOSPHERIC RESEARCH FACILITY	A6	2	7	14	6	11	2	31	23	1.348	1.401	1.964	022.127
12 WATER LEVEL AND FAULT MOVEMENT INDICATOR	B3	4	5	16	7	11	1	29	22	1.318	1.129	1.275	025.686
13 CLOSE SOLAR ORBITER	D47	3	4	12	13	10	1	22	17	1.294	1.213	1.471	018.137
14 10-M OPTICAL INTERFEROMETER	A17	18	5	7	19	7	2	18	14	1.286	1.684	2.835	010.689
15 MULTIPLANET FLYBYS AND GRAVITY ASSIST	D40	3	3	18	8	11	0	27	21	1.286	0.717	0.514	037.657
16 EVOLUTION OF PLANETARY EXPLORTATION GOALS	A34	3	7	12	7	11	3	27	22	1.227	1.602	2.565	016.854
17 HIGH RESOLUTION EARTH MAPPING RADAR	B13	3	4	18	7	10	1	28	23	1.217	1.043	1.087	026.846
18 SPACE-BASED ASTROPHYSICS RESEARCH FACILITY	A5	5	7	19	4	7	3	34	29	1.172	1.391	1.934	024.443
19 SURFACE ROVERS	D49	4	6	13	8	10	3	25	22	1.136	1.552	2.409	016.108
20 TRANSPORTATION SERVICES SATELLITES	B19	6	5	16	7	9	3	25	24	1.042	1.429	2.042	017.495
21 AUTOMATED PLANETARY STATION	A3	18	8	14	3	10	5	28	27	1.037	1.720	2.960	016.279
22 SPACE-BASED HEALTH CARE RESEARCH FACILITY	A7	21	6	14	6	9	5	22	25	0.880	1.691	2.860	013.010
23 SYNCHRONOUS METEOROLOGICAL SATELLITE	B12	4	2	10	15	11	2	12	14	0.857	1.406	1.978	008.535
24 DOPPLER MILLIHERTZ GRAVITY WAVE DETECTION	A21	4	5	5	19	7	4	12	14	0.857	2.070	4.286	005.797
25 DETECTION OF OTHER PLANETARY SYSTEMS	D9	1	3	11	14	9	3	14	17	0.824	1.550	2.404	009.032
26 PERMANENT LUNAR OUTPOST	A8	18	8	13	3	9	7	23	28	0.821	1.867	3.485	012.319
27 COMBINED MISSIONS W/PRIMARY ENG-SCIE OBJECTIVES	D76	3	6	5	13	11	5	13	16	0.813	2.136	4.563	006.086
28 SINGLE-STAGE-TO-ORBIT SHUTTLE	D97	3	1	3	2	33	1	4	5	0.800	1.789	3.200	002.236
29 ADVANCED RESOURCES/POLLUTION OBSERVATORY	B1	4	3	15	8	10	4	16	22	0.727	1.486	2.208	010.767
30 OPER OF SHUTTLE OUT OF AN EQUATORIAL LAUNCH SITE	D18	4	2	3	0	33	2	5	7	0.714	2.059	4.238	002.428
31 SOLAR POWER SATELLITE	A1A	8	6	15	3	9	7	19	28	0.679	1.765	3.115	010.765
32 EARTHWATCH (CONTINUOUS HIGH RES COVERAGE)	E2	7	4	11	10	10	5	13	20	0.650	1.756	3.082	007.403
33 ACTIVE ATMOSPHERIC TEMPERATURE PROFILE SOUNDER	B11	4	2	9	15	11	3	9	14	0.643	1.598	2.555	005.632
34 DISASTER COMMUNICATIONS SET	B17	2	4	16	5	9	6	16	26	0.615	1.627	2.646	009.834
35 MANNED PLANETARY MISSION (MARS)	A35	8	7	9	6	10	8	14	24	0.583	2.041	4.167	006.859
36 DIPLOMATIC/UN HOTLINES	B24	3	2	18	5	10	5	14	25	0.560	1.417	2.007	009.880
37 NON-TERRESTRIAL MATERIALS FOR SPACE USE	A10	9	2	12	14	8	4	10	18	0.556	1.542	2.379	006.485
38 TIME DIFFERENCE COOPERATIVE COLLISION AVOIDANCE	A27	2	2	10	14	10	4	8	16	0.500	1.633	2.667	004.899
39 LASER INTERFEROMETER GRAVITY WAVE DETECTOR	A20	3	0	15	14	8	3	9	18	0.500	1.151	1.324	007.819
40 SOLAR PENETRATOR	D46	3	4	10	10	10	6	10	20	0.500	1.850	3.421	005.405
41 STANDARDIZED PLANETARY MISSION HARDWARE	A30	3	3	15	6	10	6	12	24	0.500	1.615	2.609	007.430
42 LUNAR FARSIDE RADIO TELESCOPE	D6	2	5	13	7	7	8	12	26	0.462	1.838	3.378	006.529
43 GAMMA RAY COMPTON TELESCOPE AND POLARIMETER	F1	3	3	4	21	8	4	5	11	0.455	2.115	4.473	002.364
44 COMET "PIGGYBACK" PROBE	D44	3	4	12	7	10	7	10	23	0.435	1.805	3.257	005.540
45 JUPITER ATMOSPHERE BALLOON	D2	3	2	12	11	10	5	8	19	0.421	1.610	2.591	004.969
46 SEARCH FOR EXTRATERRESTRIAL LIFE	D38	2	4	12	7	9	8	8	24	0.333	1.834	3.362	004.362
47 2-D OPTICAL INTERFEROMETER (100 METER DIAMETER)	A18	3	1	12	15	7	5	5	18	0.278	1.526	2.330	003.277

TABLE D.2

WEIGHTING FACTORS: OUTSTANDING(3),ATTRACTIVE(1),NO OPINION(0). NO RESPONSE(0). UNATTRACTIVE(-2)

OAST MISSION OPPORTUNITY RESPONSE ANALYSIS RANKING SCHEDULE
RANKING BY MEAN SCORE

MISSION TITLE	ID	NO. LNS	NO. OF RESPONSES *	+	O	B	-	TOTAL SCORE	NUM RESP	MEAN SCORE	STD DEV	VARIANCE	RATIO
1 LANDSAT H.(10-M RES ACTIVE/PASSIVE OBSERVATIONS)	E1	7	7	14	9	10	0	42	21	2.000	0.000	0.000	000.000
2 MULTIPLANET FLYBYS AND GRAVITY ASSIST	D40	3	3	18	8	11	0	42	21	2.000	0.000	0.000	000.000
3 GEOSYNCHRONOUS BROADBAND COMPUTER LINKS	A15	8	8	19	4	9	0	54	27	2.000	0.000	0.000	000.000
4 GLOBAL SEARCH AND RESCUE LOCATOR	B15	4	6	21	4	9	0	54	27	2.000	0.000	0.000	000.000
5 PERMANENT ORBITING OUTPOST	A9	5	18	10	3	8	1	54	29	1.862	0.743	0.552	072.678
6 OCEAN EXPLORING SYSTEM	A23	11	9	16	3	11	1	48	26	1.846	0.784	0.615	061.224
7 GEOSYNCHRONOUS TELEPHONE SWITCHING UTILITY	A13	6	10	15	5	9	1	48	26	1.846	0.784	0.615	061.224
8 HIGH RESOLUTION EARTH MAPPING RADAR	B13	3	4	18	7	10	1	42	23	1.826	0.834	0.696	050.360
9 WATER LEVEL AND FAULT MOVEMENT INDICATOR	B3	4	5	16	7	11	1	40	22	1.818	0.853	0.727	046.893
10 CLOSE SOLAR ORBITER	D47	3	4	12	13	10	1	30	17	1.765	0.970	0.941	030.928
11 SPACE-BASED ATMOSPHERIC RESEARCH FACILITY	A6	2	7	14	6	11	2	38	23	1.652	1.152	1.328	032.986
12 ORBITING CIVIL COMMAND AND CONTROL STATION	A16	4	8	10	11	9	2	32	20	1.600	1.231	1.516	025.995
13 SPACE-BASED ASTROPHYSICS RESEARCH FACILITY	A5	5	7	19	4	7	3	46	29	1.586	1.240	1.537	037.097
14 HIGHLY AUTONOMOUS TELE-ROBOT	A12	5	10	14	5	8	3	42	27	1.556	1.281	1.641	032.787
15 INTERNATIONAL HALLEY COMET WATCH	A31	4	13	9	6	9	3	38	25	1.520	1.327	1.760	028.636
16 TRANSPORTATION SERVICES SATELLITES	B19	6	5	16	7	9	3	36	24	1.500	1.351	1.826	026.647
17 EVOLUTION OF PLANETARY EXPLORTATION GOALS	A34	3	7	12	7	11	3	32	22	1.455	1.405	1.974	022.776
18 SURFACE ROVERS	D49	4	6	13	8	10	3	32	22	1.455	1.405	1.974	022.776
19 10-M OPTICAL INTERFEROMETER	A17	18	5	7	19	7	2	20	14	1.429	1.453	2.110	013.765
20 SYNCHRONOUS METEOROLOGICAL SATELLITE	B12	4	2	10	15	11	2	20	14	1.429	1.453	2.110	013.765
21 NUCLEAR WASTE DISPOSAL	A2	15	13	10	5	8	4	38	27	1.407	1.448	2.097	026.243
22 LASER INTERFEROMETER GRAVITY WAVE DETECTOR	A20	3	0	15	14	8	3	24	18	1.333	1.534	2.353	015.645
23 DETECTION OF OTHER PLANETARY SYSTEMS	D9	1	3	11	14	9	3	22	17	1.294	1.572	2.471	013.995
24 ADVANCED RESOURCES/POLLUTION OBSERVATORY	B1	4	3	15	8	10	4	28	22	1.273	1.579	2.494	017.733
25 AUTOMATED PLANETARY STATION	A3	18	8	14	3	10	5	34	27	1.259	1.583	2.507	021.478
26 SINGLE-STAGE-TO-ORBIT SHUTTLE	D97	3	1	3	2	33	1	6	5	1.200	1.789	3.200	003.354
27 SPACE-BASED HEALTH CARE RESEARCH FACILITY	A7	21	6	14	6	9	5	30	25	1.200	1.633	2.667	018.371
28 DIPLOMATIC/UN HOTLINES	B24	3	2	18	5	10	5	30	25	1.200	1.633	2.667	018.371
29 ACTIVE ATMOSPHERIC TEMPERATURE PROFILE SOUNDER	B11	4	2	9	15	11	3	16	14	1.143	1.703	2.901	009.395
30 NON-TERRESTRIAL MATERIALS FOR SPACE USE	A10	9	2	12	14	8	4	20	18	1.111	1.711	2.928	011.689
31 DISASTER COMMUNICATIONS SET	B17	2	4	16	5	9	6	28	26	1.077	1.719	2.954	016.289
32 ICARUS 'PEEK-A-BOO' MISSION	D108	3	0	3	3	33	1	4	4	1.000	2.000	4.000	002.000
33 TIME DIFFERENCE COOPERATIVE COLLISION AVOIDANCE	A27	2	2	10	14	10	4	16	16	1.000	1.789	3.200	008.944
34 EARTHWATCH (CONTINUOUS HIGH RES COVERAGE)	E2	7	4	11	10	10	5	20	20	1.000	1.777	3.158	011.255
35 STANDARDIZED PLANETARY MISSION HARDWARE	A30	3	3	15	6	10	6	24	24	1.000	1.769	3.130	013.567
36 SOLAR POWER SATELLITE	A1A	8	6	15	3	9	7	28	28	1.000	1.764	3.111	015.873
37 PERMANENT LUNAR OUTPOST	A8	18	8	13	3	9	7	28	28	1.000	1.764	3.111	015.873
38 JUPITER ATMOSPHERE BALLOON	D2	3	2	12	11	10	5	18	19	0.947	1.810	3.275	009.945
39 VENUS SURFACE STATION	D11	2	1	15	8	10	6	20	22	0.909	1.823	3.325	010.971
40 2-D OPTICAL INTERFEROMETER (100 METER DIAMETER)	A18	3	1	12	15	7	5	16	18	0.889	1.844	3.399	008.677
41 OPER OF SHUTTLE OUT OF AN EQUATORIAL LAUNCH SITE	D18	4	2	3	0	33	2	6	7	0.857	1.952	3.810	003.074
42 SUPER-SYNCHRONOUS JUNKYARD	D86	5	0	5	0	33	2	6	7	0.857	1.952	3.810	003.074
43 DOPPLER MILLIHERTZ GRAVITY WAVE DETECTION	A21	4	5	5	19	7	4	12	14	0.857	1.875	3.516	006.400
44 VERY LARGE ANNULUS OPTICAL TELESCOPE (100-M DIA)	D90	3	1	13	13	7	6	16	20	0.800	1.881	3.537	008.506
45 SOLAR PENETRATOR	D46	3	4	10	10	10	6	16	20	0.800	1.881	3.537	008.506
46 COMET "PIGGYBACK" PROBE	D44	3	4	12	7	10	7	18	23	0.783	1.882	3.542	009.564
47 LUNAR FARSIDE RADIO TELESCOPE	D6	2	5	13	7	7	8	20	26	0.769	1.883	3.545	010.621

TABLE D.3

WEIGHTING FACTORS: OUTSTANDING(2),ATTRACTIVE(2),NO OPINION(0), NO RESPONSE(0), UNATTRACTIVE(-2)

OAST MISSION OPPORTUNITY RESPONSE ANALYSIS RANKING SCHEDULE

RANKING BY TOTAL SCORE

	MISSION TITLE	ID	NO. LNS	NO. OF RESPONSES					TOTAL SCORE	NUM RESP	MEAN SCORE	STD DEV	VARIANCE	RATIO
				*	+	O	B	-						
1	PERMANENT ORBITING OUTPOST	A9	5	18	10	3	8	1	45	29	1.552	0.686	0.470	065.598
2	GEOSYNCHRONOUS BROADBAND COMPUTER LINKS	A15	8	8	19	4	9	0	35	27	1.296	0.466	0.217	075.107
3	GEOSYNCHRONOUS TELEPHONE SWITCHING UTILITY	A13	6	10	15	5	9	1	34	26	1.308	0.680	0.462	050.000
4	OCEAN EXPLORING SYSTEM	A23	11	9	16	3	11	1	33	26	1.269	0.667	0.445	049.475
5	GLOBAL SEARCH AND RESCUE LOCATOR	B15	4	6	21	4	9	0	33	27	1.222	0.423	0.179	078.014
6	NUCLEAR WASTE DISPOSAL	A2	15	13	10	5	8	4	32	27	1.185	1.039	1.080	030.799
7	INTERNATIONAL HALLEY COMET WATCH	A31	4	13	9	6	9	3	32	25	1.280	0.980	0.960	032.653
8	HIGHLY AUTONOMOUS TELE-ROBOT	A12	5	10	14	5	8	3	31	27	1.148	0.907	0.823	034.179
9	SPACE-BASED ASTROPHYSICS RESEARCH FACILITY	A5	5	7	19	4	7	3	30	29	1.034	0.823	0.677	036.452
10	LANDSAT H.(10-M RES ACTIVE/PASSIVE OBSERVATIONS)	E1	7	7	14	9	10	0	28	21	1.333	0.483	0.233	057.971
11	SPACE-BASED ATMOSPHERIC RESEARCH FACILITY	A6	2	7	14	6	11	2	26	23	1.130	0.815	0.664	031.902
12	AUTOMATED PLANETARY STATION	A3	18	8	14	3	10	5	25	27	0.926	1.035	1.071	024.155
13	HIGH RESOLUTION EARTH MAPPING RADAR	B13	3	4	18	7	10	1	25	23	1.087	0.597	0.356	041.876
14	WATER LEVEL AND FAULT MOVEMENT INDICATOR	B3	4	5	16	7	11	1	25	22	1.136	0.640	0.409	039.063
15	MULTIPLANET FLYBYS AND GRAVITY ASSIST	D40	3	3	18	8	11	0	24	21	1.143	0.359	0.129	066.852
16	ORBITING CIVIL COMMAND AND CONTROL STATION	A16	4	8	10	11	9	2	24	20	1.200	0.894	0.800	026.846
17	TRANSPORTATION SERVICES SATELLITES	B19	6	5	16	7	9	3	23	24	0.958	0.858	0.737	026.807
18	EVOLUTION OF PLANETARY EXPLORTATION GOALS	A34	3	7	12	7	11	3	23	22	1.045	0.950	0.903	024.211
19	PERMANENT LUNAR OUTPOST	A8	18	8	13	3	9	7	22	28	0.786	1.134	1.286	019.400
20	SURFACE ROVERS	D49	4	6	13	8	10	3	22	22	1.000	0.926	0.857	023.758
21	SPACE-BASED HEALTH CARE RESEARCH FACILITY	A7	21	6	14	6	9	5	21	25	0.840	1.028	1.057	020.428
22	SOLAR POWER SATELLITE	A1A	8	6	15	3	9	7	20	28	0.714	1.084	1.175	018.450
23	CLOSE SOLAR ORBITER	D47	3	4	12	13	10	1	19	17	1.118	0.696	0.485	027.299
24	DISASTER COMMUNICATIONS SET	B17	2	4	16	5	9	6	18	26	0.692	1.011	1.022	017.804
25	DIPLOMATIC/UN HOTLINES	B24	3	2	18	5	10	5	17	25	0.680	0.900	0.810	018.889
26	ADVANCED RESOURCES/POLLUTION OBSERVATORY	B1	4	3	15	8	10	4	17	22	0.773	0.922	0.851	018.438
27	LUNAR FARSIDE RADIO TELESCOPE	D6	2	5	13	7	7	8	15	26	0.577	1.138	1.294	013.181
28	STANDARDIZED PLANETARY MISSION HARDWARE	A30	3	3	15	6	10	6	15	24	0.625	1.013	1.027	014.808
29	MANNED PLANETARY MISSION (MARS)	A35	8	7	9	6	10	8	15	24	0.625	1.245	1.549	012.048
30	10-M OPTICAL INTERFEROMETER	A17	18	5	7	19	7	2	15	14	1.071	0.997	0.995	015.045
31	EARTHWATCH (CONTINUOUS HIGH RES COVERAGE)	E2	7	4	11	10	10	5	14	20	0.700	1.081	1.168	012.951
32	DETECTION OF OTHER PLANETARY SYSTEMS	D9	1	3	11	14	9	3	14	17	0.824	0.951	0.904	014.721
33	COMET "PIGGYBACK" PROBE	D44	3	4	12	7	10	7	13	23	0.565	1.121	1.257	011.597
34	SEARCH FOR EXTRATERRESTRIAL LIFE	D38	2	4	12	7	9	8	12	24	0.500	1.142	1.304	010.508
35	LASER INTERFEROMETER GRAVITY WAVE DETECTOR	A20	3	0	15	14	8	3	12	18	0.667	0.767	0.588	015.645
36	NON-TERRESTRIAL MATERIALS FOR SPACE USE	A10	9	2	12	14	8	4	12	18	0.667	0.970	0.941	012.371
37	SOLAR PENETRATOR	D46	3	4	10	10	10	6	12	20	0.600	1.142	1.305	010.508
38	COMBINED MISSIONS W/PRIMARY ENG-SCIE OBJECTIVES	D76	3	6	5	13	11	5	12	16	0.750	1.291	1.667	009.295
39	SYNCHRONOUS METEOROLOGICAL SATELLITE	B12	4	2	10	15	11	2	12	14	0.857	0.864	0.747	013.889
40	JUPITER ATMOSPHERE BALLOON	D2	3	2	12	11	10	5	11	19	0.579	1.017	1.035	010.816
41	VENUS SURFACE STATION	D11	2	1	15	8	10	6	11	22	0.500	0.964	0.929	011.411
42	DOPPLER MILLIHERTZ GRAVITY WAVE DETECTION	A21	4	5	5	19	7	4	11	14	0.786	1.251	1.566	008.793
43	VENUS BATHYSPHERE	D43	2	2	13	8	10	7	10	22	0.455	1.057	1.117	009.461
44	URBAN/POLICE WRIST RADIO	B16	3	2	14	7	9	8	10	24	0.417	1.060	1.123	009.434
45	TIME DIFFERENCE COOPERATIVE COLLISION AVOIDANCE	A27	2	2	10	14	10	4	10	16	0.625	1.025	1.050	009.756
46	ACTIVE ATMOSPHERIC TEMPERATURE PROFILE SOUNDER	B11	4	2	9	15	11	3	10	14	0.714	0.994	0.989	010.060
47	VERY LARGE ANNULUS OPTICAL TELESCOPE (100-M DIA)	D90	3	1	13	13	7	6	9	20	0.450	0.998	0.997	009.018

TABLE D.4

WEIGHTING FACTORS: OUTSTANDING(2),ATTRACTIVE(1),NO OPINION(0), NO RESPONSE(0), UNATTRACTIVE(-1)

OAST MISSION OPPORTUNITY RESPONSE ANALYSIS RANKING SCHEDULE
RANKING BY RATIO (TOTAL SCORE / STD DEV)

	MISSION TITLE	ID	NO. LNS	NO. OF RESPONSES					TOTAL SCORE	NUM RESP	MEAN SCORE	STD DEV	VARIANCE	RATIO
				+	+	0	B	-						
1	GLOBAL SEARCH AND RESCUE LOCATOR	B15	4	6	21	4	9	0	33	27	1.222	0.423	0.179	078.014
2	GEOSYNCHRONOUS BROADBAND COMPUTER LINKS	A15	8	8	19	4	9	0	35	27	1.296	0.466	0.217	075.107
3	MULTIPLANET FLYBYS AND GRAVITY ASSIST	D40	3	3	18	8	11	0	24	21	1.143	0.359	0.129	066.852
4	PERMANENT ORBITING OUTPOST	A9	5	18	10	3	8	1	45	29	1.552	0.686	0.470	065.598
5	LANDSAT H.(10-M RES ACTIVE/PASSIVE OBSERVATIONS)	E1	7	7	14	9	10	0	28	21	1.333	0.483	0.233	057.971
6	GEOSYNCHRONOUS TELEPHONE SWITCHING UTILITY	A13	6	10	15	5	9	1	34	26	1.308	0.680	0.462	050.000
7	OCEAN EXPLORING SYSTEM	A23	11	9	16	3	11	1	33	26	1.269	0.667	0.445	049.475
8	HIGH RESOLUTION EARTH MAPPING RADAR	B13	3	4	18	7	10	1	25	23	1.087	0.597	0.356	041.876
9	WATER LEVEL AND FAULT MOVEMENT INDICATOR	B3	4	5	16	7	11	1	25	22	1.136	0.640	0.409	039.063
10	SPACE-BASED ASTROPHYSICS RESEARCH FACILITY	A5	5	7	19	4	7	3	30	29	1.034	0.823	0.677	036.452
11	HIGHLY AUTONOMOUS TELE-ROBOT	A12	5	10	14	5	8	3	31	27	1.148	0.907	0.823	034.179
12	INTERNATIONAL HALLEY COMET WATCH	A31	4	13	9	6	9	3	32	25	1.280	0.980	0.960	032.653
13	SPACE-BASED ATMOSPHERIC RESEARCH FACILITY	A6	2	7	14	6	11	2	26	23	1.130	0.815	0.664	031.902
14	NUCLEAR WASTE DISPOSAL	A2	15	13	10	5	8	4	32	27	1.185	1.039	1.080	030.799
15	CLOSE SOLAR ORBITER	D47	3	4	12	13	10	1	19	17	1.118	0.696	0.485	027.299
16	ORBITING CIVIL COMMAND AND CONTROL STATION	A16	4	8	10	11	9	2	24	20	1.200	0.894	0.800	026.846
17	TRANSPORTATION SERVICES SATELLITES	B19	6	5	16	7	9	3	23	24	0.958	0.858	0.737	026.807
18	EVOLUTION OF PLANETARY EXPLORTATION GOALS	A34	3	7	12	7	11	3	23	22	1.045	0.950	0.903	024.211
19	AUTOMATED PLANETARY STATION	A3	18	8	14	3	10	5	25	27	0.926	1.035	1.071	024.155
20	SURFACE ROVERS	D49	4	6	13	8	10	3	22	22	1.000	0.926	0.857	023.758
21	SPACE-BASED HEALTH CARE RESEARCH FACILITY	A7	21	6	14	6	9	5	21	25	0.840	1.028	1.057	020.428
22	PERMANENT LUNAR OUTPOST	A8	18	8	13	3	9	7	22	28	0.786	1.134	1.286	019.400
23	DIPLOMATIC/UN HOTLINES	B24	3	2	18	5	10	5	17	25	0.680	0.900	0.810	018.889
24	SOLAR POWER SATELLITE	A1A	8	6	15	3	9	7	20	28	0.714	1.084	1.175	018.450
25	ADVANCED RESOURCES/POLLUTION OBSERVATORY	B1	4	3	15	8	10	4	17	22	0.773	0.922	0.851	018.438
26	DISASTER COMMUNICATIONS SET	B17	2	4	16	5	9	6	18	26	0.692	1.011	1.022	017.804
27	LASER INTERFEROMETER GRAVITY WAVE DETECTOR	A20	3	0	15	14	8	3	12	18	0.667	0.767	0.588	015.645
28	10-M OPTICAL INTERFEROMETER	A17	18	5	7	19	7	2	15	14	1.071	0.997	0.995	015.045
29	STANDARDIZED PLANETARY MISSION HARDWARE	A30	3	3	15	6	10	6	15	24	0.625	1.013	1.027	014.808
30	DETECTION OF OTHER PLANETARY SYSTEMS	D9	1	3	11	14	9	3	14	17	0.824	0.951	0.904	014.721
31	SYNCHRONOUS METEOROLOGICAL SATELLITE	B12	4	2	10	15	11	2	12	14	0.857	0.864	0.747	013.889
32	LUNAR FARSIDE RADIO TELESCOPE	D6	2	5	13	7	7	8	15	26	0.577	1.138	1.294	013.181
33	EARTHWATCH (CONTINUOUS HIGH RES COVERAGE)	E2	7	4	11	10	10	5	14	20	0.700	1.081	1.168	012.951
34	NON-TERRESTRIAL MATERIALS FOR SPACE USE	A10	9	2	12	14	8	4	12	18	0.667	0.970	0.941	012.371
35	MANNED PLANETARY MISSION (MARS)	A35	8	7	9	6	10	8	15	24	0.625	1.245	1.549	012.048
36	COMET "PIGGYBACK" PROBE	D44	3	4	12	7	10	7	13	23	0.565	1.121	1.257	011.597
37	VENUS SURFACE STATION	D11	2	1	15	8	10	6	11	22	0.500	0.964	0.929	011.411
38	JUPITER ATMOSPHERE BALLOON	D2	3	2	12	11	10	5	11	19	0.579	1.017	1.035	010.816
39	SEARCH FOR EXTRATERRESTRIAL LIFE	D38	2	4	12	7	9	8	12	24	0.500	1.142	1.304	010.508
40	SOLAR PENETRATOR	D46	3	4	10	10	10	6	12	20	0.600	1.142	1.305	010.508
41	ACTIVE ATMOSPHERIC TEMPERATURE PROFILE SOUNDER	B11	4	2	9	15	11	3	10	14	0.714	0.994	0.989	010.060
42	TIME DIFFERENCE COOPERATIVE COLLISION AVOIDANCE	A27	2	2	10	14	10	4	10	16	0.625	1.025	1.050	009.756
43	VENUS BATHYSPHERE	D43	2	2	13	8	10	7	10	22	0.455	1.057	1.117	009.461
44	URBAN/POLICE WRIST RADIO	B16	3	2	14	7	9	8	10	24	0.417	1.060	1.123	009.434
45	COMBINED MISSIONS W/PRIMARY ENG-SCIE OBJECTIVES	D76	3	6	5	13	11	5	12	16	0.750	1.291	1.667	009.295
46	2-D OPTICAL INTERFEROMETER (100 METER DIAMETER)	A18	3	1	12	15	7	5	9	18	0.500	0.985	0.971	009.137
47	VERY LARGE ANNULUS OPTICAL TELESCOPE (100-M DIA)	D90	3	1	13	13	7	6	9	20	0.450	0.998	0.997	009.018

TABLE D.5

WEIGHTING FACTORS: OUTSTANDING(2),ATTRACTIVE(1),NO OPINION(0), NO RESPONSE(0), UNATTRACTIVE(-1)

04/30/80

OAST MISSION OPPORTUNITY RESPONSE ANALYSIS RANKING SCHEDULE
RANKING BY MEAN SCORE

	MISSION TITLE	ID	NO. LNS	NO. OF RESPONSES					TOTAL SCORE	NUM RESP	MEAN SCORE	STD DEV	VARIANCE	RATIO
				*	+	O	B	-						
1	PERMANENT ORBITING OUTPOST	A9	5	16	9	2	8	1	40	26	1.538	0.706	0.498	056.657
2	INTERNATIONAL HALLEY COMET WATCH	A31	4	13	9	3	9	2	33	24	1.375	0.875	0.766	037.714
3	GEOSYNCHRONOUS BROADBAND COMPUTER LINKS	A15	8	7	16	4	9	0	30	23	1.304	0.470	0.221	063.830
4	ORBITING CIVIL COMMAND AND CONTROL STATION	A16	4	7	9	10	9	1	22	17	1.294	0.772	0.596	028.497
5	NUCLEAR WASTE DISPOSAL	A2	15	13	8	4	8	3	31	24	1.292	0.999	0.998	031.031
6	GEOSYNCHRONOUS TELEPHONE SWITCHING UTILITY	A13	6	8	13	5	9	1	28	22	1.273	0.703	0.494	039.829
7	GLOBAL SEARCH AND RESCUE LOCATOR	B15	4	6	17	4	9	0	29	23	1.261	0.449	0.202	064.588
8	LANDSAT H.(10-M RES ACTIVE/PASSIVE OBSERVATIONS)	E1	7	4	14	8	10	0	22	18	1.222	0.428	0.183	051.402
9	OCEAN EXPLORING SYSTEM	A23	11	7	15	2	11	1	28	23	1.217	0.672	0.451	041.667
10	SPACE-BASED ATMOSPHERIC RESEARCH FACILITY	A6	2	6	12	6	11	1	23	19	1.211	0.713	0.509	032.258
11	MULTIPLANET FLYBYS AND GRAVITY ASSIST	D40	3	3	16	6	11	0	22	19	1.158	0.374	0.140	058.824
12	WATER LEVEL AND FAULT MOVEMENT INDICATOR	B3	4	5	13	6	11	1	22	19	1.158	0.688	0.474	031.977
13	EVOLUTION OF PLANETARY EXPLORTATION GOALS	A34	3	7	11	5	11	2	23	20	1.150	0.875	0.766	026.286
14	CLOSE SOLAR ORBITER	D47	3	3	11	11	10	1	16	15	1.067	0.704	0.495	022.727
15	HIGH RESOLUTION EARTH MAPPING RADAR	B13	3	3	15	7	10	1	20	19	1.053	0.621	0.386	032.206
16	HIGHLY AUTONOMOUS TELE-ROBOT	A12	5	7	13	5	8	3	24	23	1.043	0.928	0.862	025.862
17	10-M OPTICAL INTERFEROMETER	A17	18	4	7	16	7	2	13	13	1.000	1.000	1.000	013.000
18	TRANSPORTATION SERVICES SATELLITES	B19	6	4	16	5	9	2	22	22	1.000	0.756	0.571	029.101
19	SPACE-BASED ASTROPHYSICS RESEARCH FACILITY	A5	5	6	17	3	7	3	26	26	1.000	0.849	0.720	030.624
20	AUTOMATED PLANETARY STATION	A3	18	7	12	3	10	4	22	23	0.957	1.021	1.043	021.548
21	SURFACE ROVERS	D49	4	5	11	7	10	3	18	19	0.947	0.971	0.942	018.538
22	SPACE-BASED HEALTH CARE RESEARCH FACILITY	A7	21	6	14	3	9	4	22	24	0.917	0.974	0.949	022.587
23	SYNCHRONOUS METEOROLOGICAL SATELLITE	B12	4	2	9	12	11	2	11	13	0.846	0.899	0.808	012.236
24	DETECTION OF OTHER PLANETARY SYSTEMS	D9	1	3	10	11	9	3	13	16	0.813	0.981	0.963	013.252
25	DIPLOMATIC/UN HOTLINES	B24	3	2	16	5	10	3	17	21	0.810	0.814	0.662	020.885
26	SINGLE-STAGE-TO-ORBIT SHUTTLE	D97	3	1	3	2	29	1	4	5	0.800	1.095	1.200	003.653
27	ADVANCED RESOURCES/POLLUTION OBSERVATORY	B1	4	3	12	7	10	4	14	19	0.737	0.991	0.982	014.127
28	PERMANENT LUNAR OUTPOST	A8	18	7	11	2	9	7	18	25	0.720	1.173	1.377	015.345
29	OPER OF SHUTTLE OUT OF AN EQUATORIAL LAUNCH SITE	D18	4	2	3	0	29	2	5	7	0.714	1.253	1.571	003.990
30	TIME DIFFERENCE COOPERATIVE COLLISION AVOIDANCE	A27	2	2	9	12	10	3	10	14	0.714	0.994	0.989	010.060
31	SOLAR POWER SATELLITE	A1A	8	5	13	3	9	6	17	24	0.708	1.083	1.172	015.697
32	DISASTER COMMUNICATIONS SET	B17	2	4	15	2	9	6	17	25	0.680	1.030	1.060	016.505
33	GAMMA RAY COMPTON TELESCOPE AND POLARIMETER	F1	3	3	3	19	8	3	6	9	0.667	1.323	1.750	004.535
34	ACTIVE ATMOSPHERIC TEMPERATURE PROFILE SOUNDER	B11	4	2	7	13	11	3	8	12	0.667	1.073	1.152	007.456
35	DOPPLER MILLIHERTZ GRAVITY WAVE DETECTION	A21	4	4	4	17	7	4	8	12	0.667	1.303	1.697	006.140
36	COMBINED MISSIONS W/PRIMARY ENG-SCIE OBJECTIVES	D76	3	5	5	10	11	5	10	15	0.667	1.291	1.667	007.746
37	STANDARDIZED PLANETARY MISSION HARDWARE	A30	3	3	13	5	10	5	14	21	0.667	1.016	1.033	013.780
38	OZONE LAYER REPLENISHMENT/PROTECTION	B38	4	3	7	11	11	4	9	14	0.643	1.151	1.324	007.819
39	LASER INTERFEROMETER GRAVITY WAVE DETECTOR	A20	3	0	13	12	8	3	10	16	0.625	0.806	0.650	012.407
40	MANNED PLANETARY MISSION (MARS)	A35	8	6	8	5	10	7	13	21	0.619	1.244	1.548	010.450
41	EARTHWATCH (CONTINUOUS HIGH RES COVERAGE)	E2	7	3	10	8	10	5	11	18	0.611	1.092	1.193	010.073
42	COMET "PIGGYBACK" PROBE	D44	3	4	10	6	10	6	12	20	0.600	1.142	1.305	010.508
43	LUNAR FARSIDE RADIO TELESCOPE	D6	2	4	12	6	7	7	13	23	0.565	1.121	1.257	011.597
44	NON-TERRESTRIAL MATERIALS FOR SPACE USE	A10	9	1	10	13	8	4	8	15	0.533	0.990	0.981	008.081
45	JUPITER ATMOSPHERE BALLOON	D2	3	2	10	9	10	5	9	17	0.529	1.068	1.140	008.427
46	ICARUS 'PEEK-A-BOO' MISSION	D108	3	0	3	3	29	1	2	4	0.500	1.000	1.000	002.000
47	SEARCH FOR EXTRATERRESTRIAL LIFE	D38	2	4	11	4	9	8	11	23	0.478	1.163	1.352	009.458

TABLE D.6

WEIGHTING FACTORS: OUTSTANDING(2),ATTRACTIVE(1),NO OPINION(O), NO RESPONSE(O), UNATTRACTIVE(-1)

OAST MISSION OPPORTUNITY RESPONSE ANALYSIS RANKING SCHEDULE
RANKING BY MEAN SCORE

	MISSION TITLE	ID	NO. LNS	NO. OF RESPONSES *	+	0	B	-	TOTAL SCORE	NUM RESP	MEAN SCORE	STD DEV	VARIANCE	RATIO
1	PERMANENT ORBITING OUTPOST	A9	5	3	1	2	4	0	7	4	1.750	0.500	0.250	014.000
2	AUTOMATED PLANETARY STATION	A3	18	3	2	1	4	0	8	5	1.600	0.548	0.300	014.599
3	SPACE OBSERV. OF 3-D LIQ WATER DEN/VEL IN STORMS	A25	5	1	1	3	5	0	3	2	1.500	0.707	0.500	004.243
4	10-M OPTICAL INTERFEROMETER	A17	18	1	1	3	5	0	3	2	1.500	0.707	0.500	004.243
5	VERY LARGE ANNULUS OPTICAL TELESCOPE (100-M DIA)	D90	3	1	1	3	5	0	3	2	1.500	0.707	0.500	004.243
6	CLOSE SOLAR ORBITER	D47	3	2	2	2	4	0	6	4	1.500	0.577	0.333	010.399
7	SPACE-BASED ATMOSPHERIC RESEARCH FACILITY	A6	2	2	3	0	5	0	7	5	1.400	0.548	0.300	012.774
8	OCEAN EXPLORING SYSTEM	A23	11	2	3	0	5	0	7	5	1.400	0.548	0.300	012.774
9	SURFACE ROVERS	D49	4	2	3	1	4	0	7	5	1.400	0.548	0.300	012.774
10	ACTIVE ATMOSPHERIC TEMPERATURE PROFILE SOUNDER	B11	4	1	2	2	5	0	4	3	1.333	0.577	0.333	006.932
11	SYNCHRONOUS METEOROLOGICAL SATELLITE	B12	4	1	2	2	5	0	4	3	1.333	0.577	0.333	006.932
12	SEARCH FOR MARTIAN FOSSILS	D100	2	1	2	2	5	0	4	3	1.333	0.577	0.333	006.932
13	RADAR HOLOGRAPHER	E6	6	1	2	3	4	0	4	3	1.333	0.577	0.333	006.932
14	SPACE-BASED HEALTH CARE RESEARCH FACILITY	A7	21	1	3	1	5	0	5	4	1.250	0.500	0.250	010.000
15	EARTHWATCH (CONTINUOUS HIGH RES COVERAGE)	E2	7	1	3	2	4	0	5	4	1.250	0.500	0.250	010.000
16	LANDSAT H.(10-M RES ACTIVE/PASSIVE OBSERVATIONS)	E1	7	1	3	2	4	0	5	4	1.250	0.500	0.250	010.000
17	JUPITER ATMOSPHERE BALLOON	D2	3	1	3	2	4	0	5	4	1.250	0.500	0.250	010.000
18	MARS POLAR ICE SAMPLE RETURN	D13	3	1	3	2	4	0	5	4	1.250	0.500	0.250	010.000
19	MULTIPLANET FLYBYS AND GRAVITY ASSIST	D40	3	1	3	2	4	0	5	4	1.250	0.500	0.250	010.000
20	VENUS BALLOON	D42	2	1	3	2	4	0	5	4	1.250	0.500	0.250	010.000
21	WATER LEVEL AND FAULT MOVEMENT INDICATOR	B3	4	1	3	1	5	0	5	4	1.250	0.500	0.250	010.000
22	SOLAR PENETRATOR	D46	3	1	3	2	4	0	5	4	1.250	0.500	0.250	010.000
23	HIGH RESOLUTION EARTH MAPPING RADAR	B13	3	1	4	1	4	0	6	5	1.200	0.447	0.200	013.423
24	EVOLUTION OF PLANETARY EXPLORTATION GOALS	A34	3	1	4	1	4	0	6	5	1.200	0.447	0.200	013.423
25	GEOSYNCHRONOUS TELEPHONE SWITCHING UTILITY	A13	6	1	4	1	4	0	6	5	1.200	0.447	0.200	013.423
26	GLOBAL SEARCH AND RESCUE LOCATOR	B15	4	1	4	1	4	0	6	5	1.200	0.447	0.200	013.423
27	HIGHLY AUTONOMOUS TELE-ROBOT	A12	5	1	4	1	4	0	6	5	1.200	0.447	0.200	013.423
28	DIPLOMATIC/UN HOTLINES	B24	3	1	5	0	4	0	7	6	1.167	0.409	0.167	017.115
29	INTERNATIONAL HALLEY COMET WATCH	A31	4	3	3	0	3	1	8	7	1.143	1.069	1.143	007.484
30	2-D OPTICAL INTERFEROMETER (100 METER DIAMETER)	A18	3	0	2	3	5	0	2	2	1.000	0.000	0.000	000.000
31	LASER INTERFEROMETER GRAVITY WAVE DETECTOR	A20	3	0	3	2	5	0	3	3	1.000	0.000	0.000	000.000
32	GEOSYNCHRONOUS BROADBAND COMPUTER LINKS	A15	8	0	4	2	4	0	4	4	1.000	0.000	0.000	000.000
33	NUCLEAR WASTE DISPOSAL	A2	15	2	2	1	4	1	5	5	1.000	1.225	1.500	004.082
34	SEARCH FOR EXTRATERRESTRIAL LIFE	D38	2	1	3	0	5	1	4	5	0.800	1.095	1.200	003.653
35	PERMANENT LUNAR OUTPOST	A8	18	1	3	1	4	1	4	5	0.800	1.095	1.200	003.653
36	MANNED PLANETARY MISSION (MARS)	A35	8	1	3	1	4	1	4	5	0.800	1.095	1.200	003.653
37	PLANETARY ORBITER MONITORING STATIONS	D39	3	1	3	1	4	1	4	5	0.800	1.095	1.200	003.653
38	DISASTER COMMUNICATIONS SET	B17	2	1	3	1	4	1	4	5	0.800	1.095	1.200	003.653
39	TRANSPORTATION SERVICES SATELLITES	B19	6	1	3	1	4	1	4	5	0.800	1.095	1.200	003.653
40	SOLAR POWER SATELLITE	A1A	8	1	2	1	5	1	3	4	0.750	1.258	1.583	002.385
41	ADVANCED RESOURCES/POLLUTION OBSERVATORY	B1	4	1	2	2	4	1	3	4	0.750	1.258	1.583	002.385
42	STANDARDIZED PLANETARY MISSION HARDWARE	A30	3	1	2	2	4	1	3	4	0.750	1.258	1.583	002.385
43	DEEP PROBES OF ICY SATELLITES	A33	4	1	2	2	4	1	3	4	0.750	1.258	1.583	002.385
44	ORBITING CIVIL COMMAND AND CONTROL STATION	A16	4	1	2	2	4	1	3	4	0.750	1.258	1.583	002.385
45	VENUS BATHYSPHERE	D43	2	1	2	2	4	1	3	4	0.750	1.258	1.583	002.385
46	THERMAL INERTIA MAPPER	E5	3	1	1	3	4	1	2	3	0.667	1.527	2.333	001.310
47	JUPITER AIRCRAFT	D3	4	2	1	1	4	2	3	5	0.600	1.517	2.300	001.978

TABLE D.7

WEIGHTING FACTORS: OUTSTANDING(2),ATTRACTIVE(1),NO OPINION(0), NO RESPONSE(0), UNATTRACTIVE(-1)

OAST MISSION OPPORTUNITY RESPONSE ANALYSIS RANKING SCHEDULE
RANKING BY MEAN SCORE

	MISSION TITLE	ID	NO. LNS	NO. OF RESPONSES *	+	0	B	-	TOTAL SCORE	NUM RESP	MEAN SCORE	STD DEV	VARIANCE	RATIO
48	COMET "PIGGYBACK" PROBE	D44	3	2	1	1.	4	2	3	5	0.600	1.517	2.300	001.978
49	URBAN/POLICE WRIST RADIO	B16	3	0	4	1	4	1	3	5	0.600	0.894	0.800	003.356
50	ENERGY GENERATION - NUCLEAR MICROWAVE	B29	4	1	0	3	5	1	1	2	0.500	2.121	4.500	000.471
51	CATALOG OF SOLAR SYSTEMS RESOURCES	D71	2	1	0	4	4	1	1	2	0.500	2.121	4.500	000.471
52	SPACE-BASED ASTROPHYSICS RESEARCH FACILITY	A5	5	0	3	1	5	1	2	4	0.500	1.000	1.000	002.000
53	CONFIRMATION OF BLACK HOLES	D89	5	0	3	1	5	1	2	4	0.500	1.000	1.000	002.000
54	COMBINED MISSIONS W/PRIMARY ENG-SCIE OBJECTIVES	D76	3	0	3	1	5	1	2	4	0.500	1.000	1.000	002.000
55	GEOS (EARTH OBSERVATION FROM GEO AT 3-METER RES)	E3	3	0	3	2	4	1	2	4	0.500	1.000	1.000	002.000
56	VENUS SURFACE STATION	D11	2	0	3	2	4	1	2	4	0.500	1.000	1.000	002.000
57	3-D HOLOGRAPHIC TELECONFERENCING	B25	4	0	3	2	4	1	2	4	0.500	1.000	1.000	002.000
58	MANNED SOLAR ORBITING LABORATORY	D60	3	0	3	1	5	1	2	4	0.500	1.000	1.000	002.000
59	COMPREHENSIVE SOLAR SYSTEM SAMPLING	D78	3	1	2	1	4	2	2	5	0.400	1.342	1.800	001.490
60	CLIMATE MODIFICATION/HURRICANE SEEDING	A24	7	0	2	2	5	1	1	3	0.333	1.155	1.333	000.866
61	FIRE DETECTION	B2	3	0	2	3	4	1	1	3	0.333	1.155	1.333	000.866
62	DETECTION OF OTHER PLANETARY SYSTEMS	D9	1	0	2	1	6	1	1	3	0.333	1.155	1.333	000.866
63	MICROSAT (1-KM L-BAND RES FOR SOIL MOISTURE	E7	5	0	2	3	4	1	1	3	0.333	1.155	1.333	000.866
64	PLANETARY SURFACE BEACON NETWORK	A32	4	0	2	3	4	1	1	3	0.333	1.155	1.333	000.866
65	ASTEROID SEARCH SATELLITE	D72	2	0	2	3	4	1	1	3	0.333	1.155	1.333	000.866
66	LONG BASE-LINE ASTROMETRIC TELESCOPE	D52	4	0	2	2	5	1	1	3	0.333	1.155	1.333	000.866
67	DOPPLER MILLIHERTZ GRAVITY WAVE DETECTION	A21	4	0	2	2	5	1	1	3	0.333	1.155	1.333	000.866
68	TIME DIFFERENCE COOPERATIVE COLLISION AVOIDANCE	A27	2	0	2	2	5	1	1	3	0.333	1.155	1.333	000.866
69	U.N. TRUCE OBSERVATION SATELLITE	B6	4	0	2	2	5	1	1	3	0.333	1.155	1.333	000.866
70	LUNAR FARSIDE RADIO TELESCOPE	D6	2	1	1	1	5	2	1	4	0.250	1.500	2.250	000.667
71	SPACE-BASED SETI	A4	9	1	1	1	5	2	1	4	0.250	1.500	2.250	000.667
72	PERSONAL NAVIGATION WRIST SET	B33	3	0	3	1	4	2	1	5	0.200	1.095	1.200	000.913
73	SOLAR SAIL LAGRANGE POINT MISSION	D105	2	0	3	1	4	2	1	5	0.200	1.095	1.200	000.913
74	HELIOPAUSE EXPLORER	D1	3	0	0	5	5	0	0	0	0.000	0.000	0.000	000.000
75	ENERGY MONITOR	B35	3	0	1	4	4	1	0	2	0.000	1.414	2.000	000.007
76	ICARUS 'PEEK-A-BOO' MISSION	D108	3	0	0	0	10	0	0	0	0.000	0.000	0.000	000.000
77	'STANDBY' TRANSPORT OF WATER INTO ORBIT	D16	5	0	0	0	10	0	0	0	0.000	0.000	0.000	000.000
78	RAIL ANTI-COLLISION SYSTEM	B39	4	0	2	2	4	2	0	4	0.000	1.155	1.333	000.009
79	OPER OF SHUTTLE OUT OF AN EQUATORIAL LAUNCH SITE	D18	4	0	0	0	10	0	0	0	0.000	0.000	0.000	000.000
80	AIRCRAFT LASER POWERING	B31	3	0	1	3	5	1	0	2	0.000	1.414	2.000	000.007
81	MANNED LUNAR MISSION USING SHUTTLE ORBITER	D87	3	0	0	0	10	0	0	0	0.000	0.000	0.000	000.000
82	SPACE DEBRIS SWEEPER	B37	4	0	0	0	10	0	0	0	0.000	0.000	0.000	000.000
83	SUPER-SYNCHRONOUS JUNKYARD	D86	5	0	0	0	10	0	0	0	0.000	0.000	0.000	000.000
84	GAMMA RAY COMPTON TELESCOPE AND POLARIMETER	F1	3	0	1	3	5	1	0	2	0.000	1.414	2.000	000.007
85	OZONE LAYER REPLENISHENT/PROTECTION	B38	4	0	1	3	5	1	0	2	0.000	1.414	2.000	000.007
86	1-KM FRESNEL LENS	A19	6	0	1	3	5	1	0	2	0.000	1.414	2.000	000.007
87	TEXTUROMETER (1MM TO 1M VISIBLE RES)	E4	6	0	0	6	4	0	0	0	0.000	0.000	0.000	000.000
88	MASTER SPACE REFERENCE SYSTEM	A28	3	0	1	4	4	1	0	2	0.000	1.414	2.000	000.007
89	CLIMATE RESCUE	D62	4	0	1	3	5	1	0	2	0.000	1.414	2.000	000.007
90	PERSONAL COMMUNICATIONS WRIST RADIO	B23	3	0	3	0	4	3	0	6	0.000	1.095	1.200	000.009
91	DETECTION OF EXTRA-PLUTONIAN PLANETS	D8	3	0	1	4	4	1	0	2	0.000	1.414	2.000	000.007
92	SEARCH FOR RELATIVISTIC OBJECTS	D109	5	0	1	3	5	1	0	2	0.000	1.414	2.000	000.007
93	MANNED MARS AIRPLANE	D41	3	0	2	2	4	2	0	4	0.000	1.155	1.333	000.009
94	COSMOLOGICAL RANGE FINDER	A22	5	0	1	3	5	1	0	2	0.000	1.414	2.000	000.007

TABLE D.7 (Cont.)

WEIGHTING FACTORS: OUTSTANDING(2),ATTRACTIVE(1),NO OPINION(0), NO RESPONSE(0), UNATTRACTIVE(-1)

OAST MISSION OPPORTUNITY RESPONSE ANALYSIS RANKING SCHEDULE
RANKING BY MEAN SCORE

	MISSION TITLE	ID	NO. LNS	NO. OF RESPONSES *	+	O	B	-	TOTAL SCORE	NUM RESP	MEAN SCORE	STD DEV	VARIANCE	RATIO
95	VIEW OF SUN AT A DISTANCE	D79	2	0	0	0	10	0	0	0	0.000	0.000	0.000	000.000
96	SINGLE-STAGE-TO-ORBIT SHUTTLE	D97	3	0	0	0	10	0	0	0	0.000	0.000	0.000	000.000
97	LUNAR (OR ASTEROIDAL) STAGING BASE	D75	2	0	1	3	5	1	0	2	0.000	1.414	2.000	000.007
98	SEARCH FOR EARTH-APPROACHING ASTEROIDS	D30	2	0	1	5	4	0	1	1	0.000	0.000	0.000	000.000
99	NON-TERRESTRIAL MATERIALS FOR SPACE USE	A10	9	1	0	5	4	0	2	1	0.000	0.000	0.000	000.000
100	SEARCH FOR SOLAR SYSTEM ACCRETION TAIL	D50	1	0	0	4	5	1	-1	1	0.000	0.000	0.000	000.000
101	UNIVERSITY IN ORBIT	D85	4	0	2	0	5	3	-1	5	-0.200	1.095	1.200	-000.913
102	BURGLAR ALARM/INTRUSION DETECTION	B40	4	0	2	1	4	3	-1	5	-0.200	1.095	1.200	-000.913
103	UNMANNED PHOBOS LANDER	D82	1	0	1	3	4	2	-1	3	-0.333	1.155	1.333	-000.866
104	TOURS ABOARD SHUTTLE	D101	3	0	1	2	5	2	-1	3	-0.333	1.155	1.333	-000.866
105	NUCLEAR FUEL LOCATOR	B7	5	0	1	2	5	2	-1	3	-0.333	1.155	1.333	-000.866
106	ARTS AND MEDIA REPRESENTATIVES TO ORBIT	D84	3	0	1	3	4	2	-1	3	-0.333	1.155	1.333	-000.866
107	BORDER SURVEILLANCE	B8	4	0	1	3	4	2	-1	3	-0.333	1.155	1.333	-000.866
108	SHIFT POLLUTING INDUSTRIES OFF EARTH	D59	2	0	1	2	5	2	-1	3	-0.333	1.155	1.333	-000.866
109	POWER RELAY SATELLITE	B41	3	0	1	2	5	2	-1	3	-0.333	1.155	1.333	-000.866
110	INTERSTELLAR PROBE	D10	2	0	2	0	4	4	-2	6	-0.333	1.033	1.067	-001.936
111	ASTEROID AND COMET DEFLECTION	D102	2	0	1	2	4	3	-2	4	-0.500	1.000	1.000	-002.000
112	FOOD PRODUCTION IN SPACE	D67	2	0	1	2	4	3	-2	4	-0.500	1.000	1.000	-002.000
113	SOLARES (REFLECTORS FOR GROUND SOLAR POWER)	A1C	8	0	1	1	5	3	-2	4	-0.500	1.000	1.000	-002.000
114	TERRAFORM LARGER CELESTIAL BODIES	D58	3	0	1	1	5	3	-2	4	-0.500	1.000	1.000	-002.000
115	ASTEROID BEACON NETWORK	D103	3	0	1	2	4	3	-2	4	-0.500	1.000	1.000	-002.000
116	MANNED INTERSTELLAR MISSION	D22	1	1	0	0	4	5	-3	6	-0.500	1.225	1.500	-002.449
117	AGRICULTURAL ENGINEERING USING REFLECTORS	A1E	5	0	1	1	4	4	-3	5	-0.600	0.894	0.800	-003.356
118	PLANETARY GPS (GLOBAL POSITIONING SYSTEM)	A29	3	0	0	4	4	2	-2	2	-1.000	0.000	0.000	000.000
119	LOW-FREQUENCY RADIO TELESCOPE/HELIOGYRO	D104	5	0	0	3	5	2	-2	2	-1.000	0.000	0.000	000.000
120	INTERPLANETARY TV LINK	B14	3	0	0	4	4	2	-2	2	-1.000	0.000	0.000	000.000
121	INTERSTELLAR RADAR	D63	4	0	0	3	5	2	-2	2	-1.000	0.000	0.000	000.000
122	PARASOL RADIOMETER (10 METER RES L-BAND)	F8	4	0	0	4	4	2	-2	2	-1.000	0.000	0.000	000.000
123	SEARCH FOR OORT CLOUD	D51	5	0	0	3	5	2	-2	2	-1.000	0.000	0.000	000.000
124	NON-TERRESTRIAL MATERIALS FOR TERRESTRIAL USE	A11	7	0	0	4	4	2	-2	2	-1.000	0.000	0.000	000.000
125	VEHICULAR SPEED LIMIT CONTROL	B36	5	0	0	3	4	3	-3	3	-1.000	0.000	0.000	000.000
126	NETTA (NIGHT ILLUMINATION)	A1F	34	0	0	3	4	3	-3	3	-1.000	0.000	0.000	000.000
127	CLIMATE MODIFICATION WITH REFLECTORS	A1D	6	0	0	2	5	3	-3	3	-1.000	0.000	0.000	000.000
128	LUNAR MINE/FACTORY	C1	6	0	0	1	5	4	-4	4	-1.000	0.000	0.000	000.000
129	VOTING/POLLING WRIST SET	B21	3	0	0	2	4	4	-4	4	-1.000	0.000	0.000	000.000
130	LUNAR POWER SYSTEM	A1B	5	0	0	1	5	4	-4	4	-1.000	0.000	0.000	000.000
131	SPACE SETTLEMENTS	D26	3	0	0	0	5	5	-5	5	-1.000	0.000	0.000	000.000
132	ZERO GRAVITY SPORTS	D64	2	0	0	1	4	5	-5	5	-1.000	0.000	0.000	000.000
133	RESORT HOTEL IN LOW EARTH ORBIT	D24	3	0	0	1	4	5	-5	5	-1.000	0.000	0.000	000.000
134	INTERSTELLAR SETTLEMENTS	D23	1	0	0	0	4	6	-6	6	-1.000	0.000	0.000	000.000

TABLE D.7 (Cont.)

WEIGHTING FACTORS: OUTSTANDING(2),ATTRACTIVE(1),NO OPINION(0). NO RESPONSE(0). UNATTRACTIVE(-1)

ANALYSIS OF RESPONDANTS
SCORES BY DISCIPLINE

	ASTRO-PHYSICS		UTIL OF SPCE SYSTMS		COMMUNICATN		GLOBAL ENVIRONMENT		LIFE SCIENCES		PLANETARY		SOLAR		TRANSPORT		TOTAL	
ID	SCORE	MEAN	SCORE	MEAN	SCORE	MEAN	SCORE	MEAN	SCORE	MEAN	SCORE	MEAN	SCORE	MEAN	SCORE	MEAN	SCORE	MEAN
01	6	0.4	14	0.5	-3	-0.1	3	0.3	3	0.7	-2	-0.2	13	0.7	2	1.0	36	0.3
02	2	0.1	-2	-0.0	-2	-0.1	-1	-0.2	1	0.3	1	0.2	2	0.1	-2	-0.3	-1	-0.0
03	-9	-0.6	-3	-0.1	11	1.3	-1	-0.3	-3	-1.0	3	0.5	-19	-0.7	-7	-0.7	-28	-0.3
04	4	0.4	10	0.3	0	0.0	0	0.0	4	1.0	5	1.0	24	0.9	2	0.3	49	0.5
05	7	0.4	13	0.5	2	0.1	3	0.7	4	1.0	3	1.5	8	0.5	5	1.2	45	0.5
06	3	0.2	10	0.4	1	0.1	3	0.7	3	1.0	4	0.4	-2	-0.1	0	0.0	22	0.2
07	9	0.6	-1	-0.0	14	0.8	-2	-0.2	4	1.0	6	1.0	14	0.8	0	0.0	44	0.4
08	9	0.9	19	0.9	13	1.1	0	0.0	1	0.3	9	1.1	11	0.5	2	0.5	64	0.8
09	5	0.7	9	0.4	8	0.5	1	0.3	-4	-1.0	3	1.0	-2	-0.0	-1	-0.1	19	0.2
10	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	-1	-1.0	2	0.4	1	0.1
11	0	0.0	-3	-0.1	6	0.4	7	0.8	5	1.2	13	1.3	27	1.0	4	2.0	59	0.6
12	0	0.0	-4	-0.1	2	0.1	0	0.0	-2	-0.5	4	0.4	-9	-0.3	-1	-0.2	-10	-1.6
13	-3	-0.6	-12	-0.4	-7	-0.4	-5	-0.7	-2	-0.5	-5	-0.5	-7	-0.2	-1	-0.3	-42	-0.4
14	-2	-0.1	-7	-0.2	0	0.0	-1	-0.1	6	2.0	4	0.4	11	0.4	2	2.0	13	0.1
15	-1	-0.0	-5	-0.2	-6	-0.4	-1	-0.3	-1	-1.0	-1	-0.1	-4	-0.1	-3	-1.0	-22	-0.2
16	-10	-1.0	-15	-0.5	7	0.4	1	0.1	-2	-1.0	2	0.5	-11	-0.4	-1	-1.0	-29	-0.3
17	5	1.0	6	0.2	13	1.0	2	0.5	1	0.3	11	1.2	1	0.0	2	2.0	41	0.5
18	-2	-1.0	-13	-0.4	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	-15	-0.3
19	0	0.0	2	0.1	0	0.0	3	1.5	1	1.0	2	2.0	0	0.0	0	0.0	8	0.4
20	0	0.0	-5	-0.2	10	1.0	3	0.6	0	0.0	6	1.0	3	0.1	1	1.0	18	0.2
21	3	0.4	3	0.1	-3	-0.2	-2	-0.5	-1	-1.0	2	0.6	10	0.5	1	1.0	13	0.2
22	1	0.0	-2	-0.0	-7	-0.4	-1	-0.1	1	0.3	7	0.6	4	0.2	3	1.0	6	0.0
23	4	0.4	-4	-0.1	-2	-0.1	-4	-1.0	-1	-0.3	3	1.0	11	0.5	4	1.0	11	0.1
24	3	0.2	5	0.2	5	0.3	5	1.0	3	1.0	5	1.2	23	0.9	2	1.0	51	0.5
25	17	1.3	-2	-0.1	13	1.0	10	1.6	7	1.7	10	1.4	20	1.2	0	0.0	75	0.9
26	2	0.1	-7	-0.2	3	0.2	3	0.5	-2	-0.5	0	0.0	-18	-0.8	0	0.0	-19	-0.1
27	-1	-1.0	-11	-0.4	2	0.1	2	1.0	0	0.0	0	0.0	1	1.0	0	0.0	-7	-0.1
28	10	1.1	25	1.3	20	1.4	8	1.1	4	1.0	8	1.3	33	1.4	4	1.3	112	1.3
29	-4	-0.3	-10	-0.4	-5	-0.4	1	0.2	1	1.0	1	0.3	-3	-0.1	-1	-1.0	-20	-0.2
30	10	1.4	11	0.4	14	1.4	1	0.3	2	1.0	13	1.6	3	1.0	0	0.0	54	0.9
32	0	0.0	-9	-0.6	-1	-1.0	0	0.0	-1	-1.0	2	0.2	0	0.0	0	0.0	-9	-0.3
33	0	0.0	1	1.0	-4	-0.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	-3	-0.1
34	9	1.2	7	0.3	15	1.0	3	1.0	4	1.0	6	1.0	7	0.6	2	0.5	53	0.7
35	1	0.1	-14	-0.7	4	0.5	0	0.0	1	1.0	0	0.0	-7	-0.5	-1	-1.0	-16	-0.2
36	-7	-0.4	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	-7	-0.4
37	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
38	-10	-0.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	-10	-0.7
39	-1	-0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	-1	-0.0
40	3	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	3	0.2
41	1	1.0	0	0.0	0	0.0	0	0.0	0	0.0	3	1.5	19	0.9	0	0.0	23	1.0

WEIGHTING FACTORS: OUTSTANDING(2),ATTRACTIVE(1),NO OPINION(0), NO RESPONSE(0), UNATTRACTIVE(-1)

TABLE D.8

PART C: OPPORTUNITY TECHNOLOGIES

This portion of Volume III of the NASA Space Systems Technology Model presents a summary of the technology requirements data contained in all mission system and program descriptions within the earlier sections. The intent is to provide a convenient method for ascertaining the demands upon each technology discipline. The data are presented in tabular form by discipline, and where possible are plotted as a function of start date.

The technology disciplines include: power and electric propulsion; chemical propulsion; materials and structures; information systems; navigation, guidance and control; and automated operations.

ACKNOWLEDGMENT

The following NASA Headquarters personnel coordinated the preparation of the descriptions of speculative or "opportunity" technologies presented herein:

Power and Propulsion	R. W. Riebling
Chemical Propulsion	F. W. Stephenson
Materials and Structures	W. A. Brainard
Sensors	B. Rubin
Data Processing and Communications	L. B. Holcomb
Automated Operations, Navigation, Guidance and Control	W. B. Gevarter

The technical experts at NASA's field centers who furnished some of this material are identified on the pages which set forth their novel and innovative ideas.

R. W. Riebling served as overall coordinator and editor of Part C of this volume.

1 POWER

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SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: Isotope Stirling Space Power System **SPONSORING AGENCY** OSS/OAST

HQ PM: W. R. Hudson **PHONE** 755-3278 **CENTER CONTACT** F. C. Vote, JPL **PHONE** 213/354-4116

NARRATIVE DESCRIPTION: The free-piston Stirling/linear alternator represents the highest theoretical performance available for isotope-heated space power systems in the 0.3 to 2 kW range. Due to funding priorities, the Stirling was dropped from DOE development, but not before demonstration of the performance potential. Validation of the system concept and performance must be completed prior to technology readiness.

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

The Stirling Space Power System offers a potentially significant mission enhancement for planetary missions in the 1985-2000 time frame. Mass reductions on the order of 100-200 kg in the typical outer planet spacecraft are possible.

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

	ACTUALS	FORECASTS		COMMENTS
	FY 80*	FY 85*	FY 2000*	
STATUS DESCRIPTORS (1-5)	2	5	6	
CRITICAL FIGURES OF MERIT				
1. Specific power, We/kg	6.0		8.0	
2. Thermal-electric efficiency, %	18.0		35.0	
3.				
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*Assumes adequate resources applied.

SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: High Performance Amorphous Silicon Solar Arrays SPONSORING AGENCY JPL

HQ PM: L. R. Randolph PHONE 755-3278 CENTER CONTACT W. Hasbach, JPL PHONE 213/354-6132

NARRATIVE DESCRIPTION:

The use of amorphous silicon blanket (~2 μm) photovoltaic converters in space solar arrays could provide seven times the power-to-weight values achievable with high efficiency crystalline silicon arrays (>1000 W/kg).

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

Multikilowatt applications, e.g., SPS, space processing, space platforms.

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

Amorphous silicon solar cells.

	ACTUALS	FORECASTS		
	FY 80*	FY 85*	FY 2000*	COMMENTS
STATUS DESCRIPTORS (1-5)				
CRITICAL FIGURES OF MERIT				
1. W/kg		200	1500	
2. $/W		600	50	
3.				
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*Assumes adequate resources applied.

SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: Thermionic Power Conversion for NEP SPONSORING AGENCY OAST

HQ PM: J. Mullin PHONE 755-3278 CENTER CONTACT J. Mondt, JPL PHONE 213/354-6847

NARRATIVE DESCRIPTION:

High temperature direct energy conversion by thermionic emission from hot emitter and collected on cooler collector surface.

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

This technology could provide a long life power source for use with any of the electropulsion concepts, and the combined technology would be useful to deliver large scientific payloads to the orbits of the outer planets.

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

DOD and DOE developing a high temperature reactor heat source.

	ACTUALS	FORECASTS		
	FY 80*	FY 85*	FY 2000*	COMMENTS
STATUS DESCRIPTORS (1-5)	3	5	6	
CRITICAL FIGURES OF MERIT	NEP			
1. Specific power	25 W/kg	33 W/kg	40 W/kg	Assumes the NEP is developed for 1995 missions.
2. Lifetime	2 yr	4 yr	10 yr	
3.				
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*Assumes adequate resources applied.

SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: Sodium Heat Engine SPONSORING AGENCY OAST

HQ PM: W. R. Hudson PHONE 755-3278 CENTER CONTACT H. Frank, I. Stein, JPL PHONE 213/354-6043

NARRATIVE DESCRIPTION: This is an electrochemical device that converts thermal energy directly into electrical energy at thermal efficiencies up to 40%. It accepts heat at 100-200°C. The system is being developed by DOE for terrestrial applications. Its high efficiency and specific power make it appear attractive for aerospace applications. NASA should examine feasibility of the system for its missions.

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

The system appears most applicable to and could enhance near sun missions.

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

	ACTUALS	FORECASTS		
	FY 80*	FY 85*	FY 2000*	COMMENTS
STATUS DESCRIPTORS (1-5)	3	4	5	
CRITICAL FIGURES OF MERIT				
1.	20% eff. at 300 W/kg	30% eff. at 500 W/kg	40% eff. at 1000 W/kg	
2.				
3.				
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*Assumes adequate resources applied.

SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: Ultra-High Energy Lithium Battery **SPONSORING AGENCY** OAST

HQ PM: W. R. Hudson **PHONE** 755-3278 **CENTER CONTACT** H. Frank, I. Stein, JPL **PHONE** 213/354-4068

NARRATIVE DESCRIPTION: The lithium chlorate cell (Li-ClO$_3$) has a theoretical energy density of 4000 W-h/kg and practical cells are calculated to deliver 800 W-h/kg. The cell operates at temperatures near 145°C. Below 127°C the electrolyte is in the solid-state and the cell should have long shelf life. Scale up of this UCLA developed system is recommended for NASA.

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

The battery could enhance many missions which are mass limted and require very long life.

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

	ACTUALS	FORECASTS		
	FY 80*	FY 85*	FY 2000*	COMMENTS
STATUS DESCRIPTORS (1-5)	3	4	5	
CRITICAL FIGURES OF MERIT				
1.	300 W-h/kg	500 W-h/kg	800 W-h/kg	
2.				
3.				
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*Assumes adequate resources applied.

SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: Solar Boiler/MHD Generator SPONSORING AGENCY

HQ PM: W. R. Hudson PHONE 755-3278 CENTER CONTACT R. M. Jones, JPL PHONE 213/674-5388

NARRATIVE DESCRIPTION:

Sunlight is focused through a window into a chamber where it is absorbed directly by an alkali metal vapor. The alkali metal vapor is ionized and along with an inert carrier gas is heated to a high temperature and then directed into a MHD generator where the energy is extracted.

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

1. High temperature superheater window made of fused quartz or sapphire.
2. Long life MHD electrodes.

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

	ACTUALS	FORECASTS		
	FY 80*	FY 85*	FY 2000*	COMMENTS
STATUS DESCRIPTORS (1-5)	1	3	6	
CRITICAL FIGURES OF MERIT				
1. Thermal efficiency			50-70%	
2. Specific mass for 10 MW or bigger system		<20 kg/kW	<5 kg/kW	
3.				
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*Assumes adequate resources applied.

SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: Radiating-Particle-Stream Heat Rejector SPONSORING AGENCY

HQ PM: L. R. Randolph PHONE 755-3278 CENTER CONTACT R. M. Jones, JPL PHONE 213/674-5388

NARRATIVE DESCRIPTION:

A stream of small particles (dust) is heated in a container and then projected through space for a short distance and then caught in another container. When travelling, the particles radiate and cool.

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

Radiator masses may be reduced by a factor of 2 to 5 from present designs, thus improving many missions.

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

	ACTUALS	FORECASTS		
	FY 80*	FY 85*	FY 2000*	COMMENTS
STATUS DESCRIPTORS (1-5)	1	5	6	
CRITICAL FIGURES OF MERIT				
1. Radiator specific mass			30-1000 kg/MW	
2.				
3.				
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*Assumes adequate resources applied.

SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: Inertial Energy Storage Systems SPONSORING AGENCY

HQ PM: L. Randolph PHONE 755-3278 CENTER CONTACT R. Jones, JPL PHONE 213/674-5388

NARRATIVE DESCRIPTION: Rotational kinetic energy is stored in a pair of electrically conducting counter-rotating disks. A magnetic field is aligned parallel to the axis of rotation of the disks. A $\overline{V} \times \overline{B}$ voltage is induced between the rim and axis of the disks which drives a radial current when the circuit is connected across a load. The radial current interacts with the magnetic field to produce $\overline{J} \times \overline{B}$ forces which slow the disks and convert rotational K.E. to electrical power.

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN: Inertial energy systems can serve as pulse power supplies providing 0.1-10 MJ of energy in millisecond pulses with gigawatt power levels. These power supplies could possibly be used in conjunction with lasers or radars to provide remote sensing of the planets from low earth orbit. Other applications calling for energy storage systems could use inertial systems, such as pulsed thrusters (MPD, etc.).

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

	ACTUALS	FORECASTS		
	FY 80*	FY 85*	FY 2000*	COMMENTS
STATUS DESCRIPTORS (1-5)	1	3	6	
CRITICAL FIGURES OF MERIT				
1. Energy density		1×10^6 J/m^3		
2. System cost		0.05 $/J		
3. Discharge time		0.3-3.0 ms		
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*Assumes adequate resources applied.

2 PROPULSION

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SPECULATIVE TECHNOLOGIES

TITLE: ELECTRO-PROPULSION ACCELERATORS

SUBMITTER: C.H. ELDRED, NASA LARC, X3911

NARRATIVE DESCRIPTION:

THIS TECHNOLOGY ENCOMPASSES ALTERNATIVES TO THE ION ACCELERATOR IN TWO GENERAL CLASSES:
1. ELECTRICALLY ACTIVE PROPELLANTS SUCH AS MPD, AND 2. INERT PROPELLANTS SUCH AS IN THE MASS DRIVER.

RELATED MISSION OPPORTUNITIES:

GENERAL TRANSPORTATION EFFICIENCY IMPROVEMENTS.

RELATED TECHNOLOGIES:

CRITICAL FIGURES OF MERIT:

PROPULSION SYSTEM PERFORMANCE, ISP, THRUST TO MASS.

STATUS/FORECAST:

TECHNOLOGY AREA	1980	1985	2000	COMMENT
MPD	3	4	5-6	
MASS DRIVER, RAIL GUN	2-3	3	4	

1/18/1980

SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: MPD Thruster System Technology **SPONSORING AGENCY** NASA/OAST

HQ PM: W. Hudson **PHONE** 755-3278 **CENTER CONTACT** L. Rudolph, JPL **PHONE** 213/792-3478

NARRATIVE DESCRIPTION:

The magnetoplasmadynamic (MPD) thruster accelerates an electrically neutral plasma with Lorentz forces ($\bar{J} \times \bar{B}$) induced by a high current discharge across cylindrically concentric electrodes. Ordinary operation is pulsed, to provide the required high input power (~MWe) with realistic space power supplies.

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

MPD thrusters promise benefits over competitive systems, due to their high power handling capability and simple system configurations. Applications include LEO-to-GEO orbit transfer, attitude control and stationkeeping of large structures, and deep space primary propulsion.

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

Improvements in space power generation will increase the existing benefits of MPD thrusters over competing systems (such as Hg ion thrusters).

	ACTUALS	FORECASTS		
	FY 80*	FY 85*	FY 2000*	COMMENTS
STATUS DESCRIPTORS (1-5)	3	4	6	
CRITICAL FIGURES OF MERIT				
1. Specific impulse (s)	2500 Ar	5000 Ar	10,000 Ar	Adjustable.
2. Thrust efficiency	30%	50%	>50%	
3. Thrust to power (nt/kW)	0.025	0.035		
4. System mass to power (kg/kW)		1.5	0.15	One thruster system can handle up to 10 MWe input power.
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*Assumes adequate resources applied.

SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: Ambient Magnetic Field Wire Thruster SPONSORING AGENCY

HQ PM: W. R. Hudson PHONE 755-3278 CENTER CONTACT L. K. Rudolph, JPL PHONE 213/354-3478

NARRATIVE DESCRIPTION: The interaction between the current in a wire and a planetary magnetic field induces a force perpendicular to the field and the wire, which is distributed uniformly along the wire length. This thruster can be configured to provide torques on a structure, if the wire is a closed-loop, or vector forces, if the wire ends are separated by a conducting space plasma which carries the return current.

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN: Attaching such a wire to a large space structure allows the thrust to be applied to the structure without distoring the structure shape as would happen with ordinary thruster point forces. This feature makes this thruster system ideal for attitude control and stationkeeping of large structures in earth orbit.

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

Space power, and spacecraft-environmental interactions.

	ACTUALS	FORECASTS		
	FY 80*	FY 85*	FY 2000*	COMMENTS
STATUS DESCRIPTORS (1-5)	1	3	6	Status depends on existance of large structures for testing.
CRITICAL FIGURES OF MERIT				
1. Specific impulse	infinite			
2. Thrust to power		0.6 nt/kW		Depends strongly on orbit altitude.
3.				
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*Assumes adequate resources applied.

SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: Deuterium Fusion Rocket SPONSORING AGENCY NASA/OAST

HQ PM: L. R. Randolph PHONE 755-3278 CENTER CONTACT T. Auslander, JPL PHONE 213/354-4413

NARRATIVE DESCRIPTION: Deuterium fusion is currently being developed in Project Nova for generation of electrical power. Utilization of deuterium as a tri-propellant in a rocket can enhance the combustion process if fusion can be achieved. A program beginning with basic principle investigation followed by concept development and demonstration is required.

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

Heavy deep space probes, distant planet orbiters and landers, planet satellite landers and orbiters, sample return missions

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

Deuterium encapsulation, development of fusion, high temperature materials.

	ACTUALS	FORECASTS		
	FY 80*	FY 85*	FY 2000*	COMMENTS
STATUS DESCRIPTORS (1-5)	1	2-3	4-5	
CRITICAL FIGURES OF MERIT				
1. Specific impulse				
2.				
3.				
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SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: Free Radical Combustion in Rocket Engines SPONSORING AGENCY NASA/OAST

HQ PM: F. W. Stephenson, Jr. PHONE 755-3147 CENTER CONTACT T. Auslander, JPL PHONE 213/354-4413

NARRATIVE DESCRIPTION: Free radicals in combustion will release potentially 2-3 times more energy, depending on the radicals involved. The basic concept is to produce the free radical propellants on earth--then use the propellants in space. Because of the high reactivity of the free radicals, storage is a significant problem. An investigation oriented toward free radical earth storable and space storable propellants is proposed. A laboratory test program and then engine development would follow.

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

Heavy deep space probes, distant planet satellite probes and landers, sample return missions.

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

Free radical storage, free radical production, high temperature materials.

	ACTUALS	FORECASTS		
	FY 80*	FY 85*	FY 2000*	COMMENTS
STATUS DESCRIPTORS (1-5)	1	2-3	5-6	
CRITICAL FIGURES OF MERIT				
1. Specific impulse (s)		600	900	
2.				
3.				
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*Assumes adequate resources applied.

SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: Advanced High Density Propellant SPONSORING AGENCY NASA/OAST

HQ PM: F. W. Stephenson, Jr. PHONE 755-3147 CENTER CONTACT T. W. Auslander, JPL PHONE 213/354-4413

NARRATIVE DESCRIPTION:

The fluorine-hydrogen propellant combination offers the highest performance potential for conventional chemical rockets. Utilization in the metallized form can improve that performance level by a factor of 2 to 3. Therefore, a program to determine feasibility of using metallic fluorine and metallic hydrogen as a high density bipropellant combination for propulsion systems is proposed.

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

Heavy deep space probes, distant planet orbiters and landers.

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

Hydrogen and fluorine metallization development.

	ACTUALS	FORECASTS		
	FY 80*	FY 85*	FY 2000*	COMMENTS
STATUS DESCRIPTORS (1-5)	1	2	3-4	
CRITICAL FIGURES OF MERIT				
1. Specific impulse				
2.				
3.				
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*Assumes adequate resources applied.

SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: Electrically Augmented High Thrust Rocket Propulsion **SPONSORING AGENCY** NASA/OAST

HQ PM: W. R. Hudson **PHONE** 755-3278 **CENTER CONTACT** T. Auslander, JPL **PHONE** 213/354-4413

NARRATIVE DESCRIPTION: The exhaust from chemical rockets can be accelerated through electrical energy transfer in the exhaust. A 3:1 performance increase may be possible. The approach would utilize an existing spacecraft power supply (such as with an on-board supply for electrical thrusters) for the augmentation of a small bipropellant engine for a kick-stage or de-orbit engine. It is proposed a laboratory model be constructed with subsequent design and construction of a demonstration firing test unit.

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

Kick-stage, de-orbit stages.

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

Electrical power generation efficiency, high temperature materials.

	ACTUALS	FORECASTS		COMMENTS
	FY 80*	FY 85*	FY 2000*	
STATUS DESCRIPTORS (1-5)	1-2	3-4	6	
CRITICAL FIGURES OF MERIT				
1. Thrust level		10 LB_F	100 LB_F	
2. Specific impulse		700 s	1000 s	
3.				
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*Assumes adequate resources applied.

SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: Metastable Helium Rocket Propulsion SPONSORING AGENCY NASA/OAST

HQ PM: F. W. Stephenson, Jr. PHONE 755-3147 CENTER CONTACT F. A. Anderson, JPL PHONE 213/354-3167

NARRATIVE DESCRIPTION:

Theoretically, metastable helium is helium which has absorbed sufficient energy to cause one electron to move to its next higher quantum level. Thus returning to its ground state quantum level releases a large amount of energy, heating the helium which serves as its own working fluid in a rocket engine.

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

This technology will supply ultra-high propulsion energy for a high energy mission, such as escaping the solar system. A 4% metastable helium in a helium diluent would produce an I_{sp} more than twice the current solid rocket I_{sp} (300 s to 650 s) at the same combustion exhaust temperatures (6000°F).

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

Method of storing the helium and technique to release the energy on demand.

	ACTUALS	FORECASTS		
	FY 80*	FY 85*	FY 2000*	COMMENTS
STATUS DESCRIPTORS (1-5)				
CRITICAL FIGURES OF MERIT				
1. I_{sp} = 650 s (4% He)				1. More than double present I_{sp} = 300 s, and thus result in larger payload or deeper missions in less flight time.
2. I_{sp} = 850 s (8% He, 1000°F)				2. Same as above if material can match temperature.
3.				
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*Assumes adequate resources applied.

SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: Nuclear Fission Enhanced Solid Propellant Rocket Fuel **SPONSORING AGENCY** NASA/OAST/DOE

HQ PM: F. W. Stephenson, Jr. **PHONE** 755-3147 **CENTER CONTACT** B. H. Morrison, JPL **PHONE** 213/354-7295

NARRATIVE DESCRIPTION:

Load the chemical solid propellant with micro-capsules containing U^{235} or Pu^{239} in a noncritical configuration. When the chemical fuel burns, the nuclear fueled plasma assumes a critical configuration and fissions. This supplies additional thermal energy to the working fluid and increases the exhaust gas temperature.

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

Since $I_{sp} \sim \sqrt{T}$ higher performance will be available, larger payload capability, escape from solar influence. I_{sp} in the 1000-1500 s range would be possible.

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

Improvements in high temperature performance of chambers, nozzles, and exit cones to withstand temperatures in the 9000-10,000°F range. Control of exhaust products would be required for testing on the ground or testing in space.

	ACTUALS	FORECASTS		
	FY 80*	FY 85*	FY 2000*	COMMENTS
STATUS DESCRIPTORS (1-5)	1-2	3	6	
CRITICAL FIGURES OF MERIT				
1. I_{sp} = 1000-1500 s				This I_{sp} would allow large payload systems capable for missions to be flown in 1990s.
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3.				
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*Assumes adequate resources applied.

SPECULATIVE TECHNOLOGIES

TITLE: EXTRATERRESTRIAL PROPELLANTS

SUBMITTER: C.H. ELDRED, NASA LARC, X3911

NARRATIVE DESCRIPTION:

NUMEROUS STUDIES HAVE SUGGESTED THE USE OF LUNAR AND PLANETARY MATERIALS FOR MISSION USES INCLUDING FOR PROPULSION. THESE CONCEPTS INCLUDE OXYGEN AND METHANE RECOVERY FROM PLANETARY ATMOSPHERES AND OXYGEN AND ALUMINUM RECOVERY FROM LUNAR MATERIALS. ALSO, THE USE OF INERT MATERIALS FOR SYSTEMS SUCH AS THE MASS DRIVER.

RELATED MISSION OPPORTUNITIES:

PLANETARY RETURN MISSIONS LUNAR/ASTEROID MATERIAL UTILIZATION.

RELATED TECHNOLOGIES:

ELECTRO-ACCELERATORS

CRITICAL FIGURES OF MERIT:

MASS OF PROPELLANT PRODUCTION SYSTEM, PERFORMANCE OF RELATED PROPULSION SYSTEM.

STATUS/FORECAST:

TECHNOLOGY AREA	1980	1985	2000	COMMENT
GASEOUS RECOVERY	2	4	5	
RECOVERY FROM SOLIDS	2	3	4	

1/18/1980

SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: In Situ Propellant Generation Via Photoelectrocatalysis SPONSORING AGENCY

HQ PM: L. R. Randolph PHONE 755-3278 CENTER CONTACT A. Gupta, JPL PHONE 213/792-5783

NARRATIVE DESCRIPTION:

A photoelectrocatalytic reactor will be used to reduce CO_2 or H_2O available on planetary surfaces to fuels e.g., CH_4 or CH_3OH, and O_2 utilizing solar photons.

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

Mars sample return, investigation of Jovian moons.

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

	ACTUALS	FORECASTS		
	FY 80*	FY 85*	FY 2000*	COMMENTS
STATUS DESCRIPTORS (1-5)				
CRITICAL FIGURES OF MERIT 1. 2. 3. . . .	Basic principles well understood; concept formulated; 12% solar conversion efficiency demonstrated in laboratory ....cont....	Expect 12-20% efficiency and excellent stability (>10^4 cycles)		..... bench; Texas Instruments is carrying out breadboard testing of this technology for DOE.

*Assumes adequate resources applied.

SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: In Situ Process Cryogenic Cooler **SPONSORING AGENCY** NASA/OAST

HQ PM: F. W. Stephenson, Jr. **PHONE** 755-3147 **CENTER CONTACT** R. Richter, JPL **PHONE** 213/354-3253

NARRATIVE DESCRIPTION:

The in situ propellant production process and propellant storage requires a cryogenic cooler of high efficiency and long life cycle. The life of the cooler can be extended by employing bellows which eliminate the need for sliding seals. The efficiency of the cooler can be increased substantially by heating the hot cylinder with a heat pipe thereby achieving a higher operating temperature at a lower input temperature.

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

The exploration of extraterrestrial bodies and the return of sample material is a logical follow-up to the present exploration of the solar system. Stop-overs on the Jovian satellites are a requirement for the closer examination of the Jovian system. Such missions will be possible only with the availability of an in situ propellant production system which includes a cryogenic cooler.

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

High temperature heat pipes with high power capacity.

	ACTUALS	FORECASTS		
	FY 80*	FY 85*	FY 2000*	COMMENTS
STATUS DESCRIPTORS (1-5)	1	2-5	6	
CRITICAL FIGURES OF MERIT				
1. Cooling capacity		4.5 W	45 W	
2. Power requirement		450 W therm.	3500 W therm.	
3. Life cycle		1 yr	5 yr	
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*Assumes adequate resources applied.

SPECULATIVE TECHNOLOGIES

TITLE: HIGH ENERGY ROCKET PROPELLANTS

SUBMITTER: C.H. ELDRED, NASA LARC, X3911

NARRATIVE DESCRIPTION:

CONCEPTUALLY METASTABLE CHEMICALS, ATOMIC/METALLIC HYDROGEN, AND ANTIMATTER OFFER HIGH PROPULSION PERFORMANCE POTENTIAL. WHETHER OR NOT THAT POTENTIAL IS REALIZABLE IN A PRACTICAL PROPULSION DEVICE IS UNCERTAIN.

RELATED MISSION OPPORTUNITIES:

GENERAL TRANSPORTATION PERFORMANCE IMPROVEMENTS.

RELATED TECHNOLOGIES:

THERMAL ROCKET MATERIALS

CRITICAL FIGURES OF MERIT:

PROPULSION SYSTEM COST AND PERFORMANCE. SPECIFIC IMPULSE.

STATUS/FORECAST:

TECHNOLOGY AREA	1980	1985	2000	COMMENT
METASTABLE CHEMICALS	1	2	3	
ATOMIC HYDROGEN	2	3	4	LERC RESEARCH
METALLIC HYDROGEN	1	1	2	LERC RESEARCH
ANTIMATTER	1	1	2	HAS BEEN PRODUCED

1/18/1980

SPECULATIVE TECHNOLOGIES

TITLE: NUCLEAR SYSTEMS - TRANSPORTATION

SUBMITTER: C.H. ELDRED, NASA LARC, X3911

NARRATIVE DESCRIPTION:

THIS TECHNOLOGY INCLUDES NUCLEAR-ELECTRIC POWER COUPLED TO AN ELECTRO-PROPULSIVE DEVICE, VARIOUS NUCLEAR ROCKET CONCEPTS INCLUDING SOLID CORE, COLLOID CORE, AND GAS CORE SYSTEMS, AS WELL AS BOMBLET CONCEPTS. FUSION OPTIONS COULD BE UTILIZED IN THE FAR TERM.

RELATED MISSION OPPORTUNITIES:

ENABLES HIGHLY ENERGETIC, LONG DURATION MISSIONS, ESPECIALLY TO OUTER PLANETS AND INTERSTELLAR REGIONS. LIGHT BULB AND COLLOID CORE SYSTEMS COULD APPLY TO EARTH-TO-ORBIT MISSIONS IF SAFETY ISSUES WERE RESOLVED.

RELATED TECHNOLOGIES:

LASERS FOR BOMBLET DETONATION

CRITICAL FIGURES OF MERIT:

POWER PER MASS, COST, SAFETY.

STATUS/FORECAST:

TECHNOLOGY AREA	1980	1985	2000	COMMENT
NUCLEAR-ELECTRIC	6	6	6	
COLLOID CORE	4	5	6	
LIGHT BULB	3	4	5	
FUSION BOMBLETS	1	2	4	

1/18/1980

SPECULATIVE TECHNOLOGIES

TITLE: BEAMED ENERGY SYSTEMS - TRANSPORTATION

SUBMITTER: C.H. ELDRED, NASA LARC, X3911

NARRATIVE DESCRIPTION:

THIS TECHNOLOGY ENCOMPASSES MICROWAVE, LASER, AND PARTICLE BEAM SYSTEMS. LOW POWER LEVEL BEAM-TO-ELECTRIC POWER SYSTEMS MAY HAVE NEAR-TERM POTENTIAL. HIGH POWER LEVEL SYSTEMS SHARE WEAPON SYSTEM TECHNOLOGY; HOWEVER, WEAPON POTENTIAL MAY INHIBIT TRANSPORTATION APPLICATIONS.

RELATED MISSION OPPORTUNITIES:

GENERAL NEAR EARTH TRANSPORTATION EFFICIENCY IMPROVEMENTS.

RELATED TECHNOLOGIES:

THERMAL ROCKET MATERIALS.

CRITICAL FIGURES OF MERIT:

PROPULSION SYSTEM PERFORMANCE, ISP, THRUST-TO-MASS. ENERGY TRANSMISSION EFFICIENCY AND SAFETY.

STATUS/FORECAST:

TECHNOLOGY AREA	1980	1985	2000	COMMENT
BEAM-TO-ELECTRIC POWER	3	4	6	
BEAM-TO-THERMAL ROCKET	2	3	4	

1/18/1980

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MATERIALS AND STRUCTURES

Total Mass

Physical Size

Flight Duration

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SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: Refining of Nonterrestrial Materials **SPONSORING AGENCY** NASA/JSC

HQ PM: L. A. Harris **PHONE** 755-2364 **CENTER CONTACT** R. Williams, JSC **PHONE** 713/483-2781

NARRATIVE DESCRIPTION: These studies concentrate on: (A) recovery of free O_2 from carbonous gases by high temperature gas phase electrolysis; (B) lunar soil separation into its constituent parts by fluidless mineral separation techniques; and (C) the recovery of photovoltaic grade silicon from lunar material by chemical processing.

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

Solar power satellite, lunar/space bases, Mars (or planetary) return mission, in situ analysis of planetary surface materials.

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

	ACTUALS	FORECASTS		
	FY 80*	FY 85*	FY 2000*	COMMENTS
STATUS DESCRIPTORS (1-5)	A: 1 B: 1 C: 1	3 2-3 3-4	6 ? 6 (?)	Attached.
CRITICAL FIGURES OF MERIT				
(A) Percent oxygen recovered/watt/time	?	?	?	(A) Changes as technology matures to oxygen yield/weight.
(B) Purity of mineral separate/weight of soil/time	?	?	?	
(C) 1. Weight of Si/weight reactants	?	?	?	
2. Purity of Si				

*Assumes adequate resources applied.

ATTACHMENT for Refining on Nonterrestrial Materials

(A) Principle is proven, but oxygen pumping rather than electrolysis is the source of oxygen. Photolytic and catalytic phenomena need to be stud.

(B) Theory exists as does some terrestrial technology. Modification to lunar conditions and actual efficiencies are unknown.

(C) Theory exists. Laboratory measurements of actual efficiencies and purity are needed. Several process options and materials need to be evaluated. Although similar technologies exist currently, none of these use chemically complex natural substances as starting material.

SPECULATIVE TECHNOLOGIES

TITLE: MATERIALS - TRANSPORTATION

SUBMITTER: C.H. ELDRED, NASA LARC, X3911

NARRATIVE DESCRIPTION:

MATERIAL PROPERTIES APPEAR TO BE LIMITING FACTORS IN THE REALIZATION OF THESE CONCEPTS:

1. SOLAR SAIL MATERIAL, MASS PER AREA
2. SPACE ELEVATOR SUPPORT CABLE, STRENGTH-TO-DENSITY RATIO
3. THERMAL ROCKET CHAMBER, TEMPERATURE LIMITS

RELATED MISSION OPPORTUNITIES:

1. LIGHT WEIGHT SOLAR SAIL MATERIALS MAY BE FEASIBLE WITH SPACE MANUFACTURING.
2. LOW COST EARTH-TO-GEO TRANSPORTATION IF HIGH TRAFFIC RATES.

RELATED TECHNOLOGIES:

CRITICAL FIGURES OF MERIT:

AS NOTED ABOVE

STATUS/FORECAST:

TECHNOLOGY AREA	1980	1985	2000	COMMENT
SOLAR SAIL MATERIALS	3	4	6	
ELEVATOR CABLE	2	3	3	
ROCKET CHAMBER MATERIALS	3	4	5	

1/18/1980

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4 INFORMATION SYSTEMS

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SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: Optical Disc Data Storage SPONSORING AGENCY Commercial/NASA

HQ PM: L. Holcomb PHONE 755-2414 CENTER CONTACT R. Hartenstein, GSFC PHONE 301/344-5659

NARRATIVE DESCRIPTION:

Use of optical signals to record digital data on a metallic or photographic disc. Very high data density $\approx 10^{11}$ to 10^{12} bits per device (on-board).

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

Deep space orbiting data satellite, deep space spacecraft, high rate spacecraft which will compete for crowded TDRSS single access channel.

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

	ACTUALS	FORECASTS		COMMENTS
	FY 80*	FY 85*	FY 2000*	
STATUS DESCRIPTORS (1-5)		3-4		
CRITICAL FIGURES OF MERIT				
1.				
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*Assumes adequate resources applied.

SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: VLSI SPONSORING AGENCY Industry/DoD/NASA

HQ PM: M. Sokoloski PHONE ______ CENTER CONTACT ______ PHONE ______

NARRATIVE DESCRIPTION:

Very high density large scale integrated circuits with line widths of 0.5 μm with 10^6-10^7 gates per chip will enable very powerful compact on-board computers.

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

Capability to perform on-board processing of high rate, sensor data such as SAR and CCD imagers.

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

	ACTUALS	FORECASTS		
	FY 80*	FY 85*	FY 2000*	COMMENTS
STATUS DESCRIPTORS (1-5)		4		
CRITICAL FIGURES OF MERIT				
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*Assumes adequate resources applied.

SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: Electron Beam Data Storage SPONSORING AGENCY DARPA

HQ PM: L. Holcomb PHONE 755-2414 CENTER CONTACT J. Sos, GSFC PHONE 301/344-7213

NARRATIVE DESCRIPTION:

Use of electron beams to record digital data on metallic disc. Very high data density 10^{13}-10^{14} bits per device (on-board).

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

Use to store large data base in orbit. Can be used to provide detailed ground maps for comparison.

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

Surface physics.

	ACTUALS	FORECASTS		COMMENTS
	FY 80*	FY 85*	FY 2000*	
STATUS DESCRIPTORS (1-5)		2-3	4-5	
CRITICAL FIGURES OF MERIT				
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*Assumes adequate resources applied.

SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: Josephson Junction Computer SPONSORING AGENCY IBM

HQ PM: L. Holcomb PHONE 755-2414 CENTER CONTACT ______ PHONE ______

NARRATIVE DESCRIPTION:

Very high speed switch which could enable extremely fast pipeline computer for space or ground use.

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

Very complex computing functions such as SAR.

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

Cryogenic cooler [high thermal power (He temperature)].

	ACTUALS	FORECASTS		
	FY 80*	FY 85*	FY 2000*	COMMENTS
STATUS DESCRIPTORS (1-5)		3	5	
CRITICAL FIGURES OF MERIT				
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*Assumes adequate resources applied.

SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: Very High Speed Integrated (VHSI) Electronics SPONSORING AGENCY DoD

HQ PM: B. Rubin PHONE 755-2414 CENTER CONTACT R. Nixon , JPL PHONE 213/354-4268

NARRATIVE DESCRIPTION:

Development of large scale, very high speed integrated electronic circuits using gallium arsenide (GaAs) as the base material. The high mobility in GaAs will result in circuitry for high speed data processing.

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

All missions where data processing is required at high bit rate.

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

	ACTUALS	FORECASTS		
	FY 80*	FY 85*	FY 2000*	COMMENTS
STATUS DESCRIPTORS (1-5)	1	3	6	
CRITICAL FIGURES OF MERIT				
1.				
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*Assumes adequate resources applied.

SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: Adaptive Optics/Rotating Line Interferometers SPONSORING AGENCY DARPA/NASA

HQ PM: J. Lundholm PHONE 755-2414 CENTER CONTACT C. Jones, MSFC PHONE 205/453-1590

NARRATIVE DESCRIPTION:

Optical configurations which have low "glass" to aperture ratios, and which achieve two dimensional image resolution with resolution commensurate with the aperture by using intensity summing of sequential images obtained from different orientations of a non-redundant linear array of apertures.

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

Advanced astronomy missions, such as a telescope with 100 meter aperture resolving potential.

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

1. Sensing of large structure deformations to optical tolerances with subsequent static and dynamic control.
2.

	ACTUALS	FORECASTS		
	FY 80*	FY 85*	FY 2000*	COMMENTS
STATUS DESCRIPTORS (1-5)	1	3	7 optimistic 5 probable	FY 85 level 3 based on theoretical, computer simulated, and laboratory demonstration of registration of the sequential images to buildup suitable signal-to-noise at the higher spatial frequencies.
CRITICAL FIGURES OF MERIT No single figure stands out today. The equation needs to be written which relates object radiance character, integration time, array linearity and fill factor, registration errors, and S/N achievable as a function of spatial frequency. From this equation(s), component performance figures of merit can be quantified.				

*Assumes adequate resources applied.

5 AUTOMATED OPERATIONS

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SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: Very Long Life Autonomous Spacecraft Control Systems **SPONSORING AGENCY** NASA/OAST Electronics & Automation

HQ PM: H. A. Rediess **PHONE** ________ **CENTER CONTACT** L. F. McGlinchey, JPL **PHONE** 213/354-4716

NARRATIVE DESCRIPTION:

To develop concepts for fully autonomous (self-test and automatic reconfiguration) very long life (greater than 20 years) spacecraft control systems for outer planet and initial interstellar exploration.

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

An outermost planet and interstellar precursor mission in the 2000 time period. Typical science goals would include: (1) precision remote sensing of outer planet satellite surfaces/atmospheres; (2) fields/particles experiments in planetary environments and galactic space; (3) study of phenomena separating solar system and galactic space.

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

(1) Control systems that virtually function without expendables and moving parts (e.g., fiber optics, interferometric sensors, VLSI); (2) very long life exposure resistant materials; (3) new propulsion concepts (e.g., gravity wave, nuclear electric); (4) nuclear electric power.

	ACTUALS	FORECASTS		
	FY 80*	FY 85*	FY 2000*	COMMENTS
STATUS DESCRIPTORS (1-5)	1	2-3	4-6	Technology readiness for 20 yr precursor mission in 1995-2000 time frame.
CRITICAL FIGURES OF MERIT				
1. Life expectancy (MTBF)	5 yr	7 yr	20-30 yr	Investigation of basic principles (1) should start at a low level ($60K) in FY 81. This type of mission is the logical evolution of the planetary exploration program and would provide enabling technologies to initiate galactic exploration.
2. Computer speed/power product (pJ)	10^9	10^8	10^5	
3. Specific impulse (s)	300	300	$>10^4$	
4. Memory weight (bits/kg)	10^4	10^5	10^9	

*Assumes adequate resources applied.

SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: Self-Replicating Autonomous Robots . SPONSORING AGENCY NASA

HQ PM: William B. Gevarter PHONE 755-8503 CENTER CONTACT G. von Tiesenhausen MSFC PHONE 205/872-2789

NARRATIVE DESCRIPTION:

Machines which can produce copies of itself from local materials and can act autonomously to carry out complex goals.

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

Exponential exploration of galaxy without any additional earth resources, once initial set of robots have been placed on a favorable planet.

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

Ability to transform local resources into finished products under autonomous computer control. Ability to express design and growth of the robot as a computer (genetic code) autonomous robot.

	ACTUALS	FORECASTS		
	FY 80*	FY 85*	FY 2000*	COMMENTS
STATUS DESCRIPTORS (1-5)	1	2	3	
CRITICAL FIGURES OF MERIT				
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*Assumes adequate resources applied.

SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: Multi-Purpose Robots SPONSORING AGENCY NASA

HQ PM: William B. Gevarter PHONE 755-8503 CENTER CONTACT Carl Rouff, JPL PHONE 213/354-6101

NARRATIVE DESCRIPTION:

Multi-purpose robots

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

Space servicing, assembly, repair, surface exploration

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

1. Automatic decision-making, logic of planning
2. Domain knowledge representation
3. Scene analysis and pattern recognition
4. Manipulation

	ACTUALS	FORECASTS		COMMENTS
	FY 80*	FY 85*	FY 2000*	
STATUS DESCRIPTORS (1-5)	3	4	5	
CRITICAL FIGURES OF MERIT				
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*Assumes adequate resources applied.

SPECULATIVE OR "OPPORTUNITY" TECHNOLOGIES

TITLE: Semi-Autonomous Planning and Decision-Making Aids SPONSORING AGENCY NASA

HQ PM: William B. Gevarter PHONE 755-8503 CENTER CONTACT Len Friedman, JPL PHONE 213/354-3888

NARRATIVE DESCRIPTION:

S/W that enables that user or the spacecraft to use a knowledge base and automatic problem solver to aid in real-time decision making.

MISSION OPPORTUNITIES ARISING FROM READINESS OF THIS TECHNOLOGY, IF KNOWN:

Autonomous exploration of outer planets--where round-trip communication time is long.

OTHER TECHNOLOGIES WHOSE READINESS THIS TECHNOLOGY DEPENDS UPON, IF ANY:

1. Automatic problem solving
2. Data base organization

	ACTUALS	FORECASTS		
	FY 80*	FY 85*	FY 2000*	COMMENTS
STATUS DESCRIPTORS (1-5)	2	4	6	
CRITICAL FIGURES OF MERIT				
1.				
2.				
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*Assumes adequate resources applied.

ACKNOWLEDGMENT OF CONTRIBUTORS

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